MASSACHUSETTS BAY DISPOSAL SITE MANAGEMENT PLAN

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PREPARED BY:

U.S. EPA REGION 1 (NEW ENGLAND)
OFFICE OF ECOSYSTEM PROTECTION
WATER QUALITY UNIT

WITH

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I. OVERVIEW

U.S. EPA Region 1-New England and the U.S. Army Corps of Engineers New England Division (NED) have prepared this site management plan (SMP) for the Massachusetts Bay Disposal Site (MBDS) to ensure that the site is managed to minimize adverse effects of disposal on the marine environment. The MBDS is an open water, ocean disposal site for dredged material designated in 1993. Currently, this site receives more dredged material, about 300,000 cubic meters annually, than any other site in New England north of Long Island Sound.

Management plans for ocean dredged material disposal sites are required pursuant to §102(c) of the Marine Protection, Research, and Sanctuaries Act (MPRSA, or the Act), as amended by §506(a) of the Water Resources Development Act (WRDA) of 1992. In accordance with MPRSA (section 103(a)) disposal activities at the site "will not unreasonably degrade or endanger human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities." This plan synthesizes prior site monitoring results, outlines a monitoring program for the site and updates the site management and monitoring agreements between the U.S. Environmental Protection Agency New England (the EPA) and the U.S. Army Corps of Engineers New England Division (the Corps, USACE, or NED). The data gathered from the monitoring program will be routinely evaluated to determine whether modifications in site usage, management, or testing protocols are warranted.

As discussed in the guidance for development of site management plans issued by EPA and the Corps ("Guidance Document for Development of Site Management Plans for Ocean Dredged Material Disposal Sites", February 1996), management of the site involves: regulating the times, quantity, and physical/chemical characteristics of dredged material that is dumped at the site; establishing disposal controls, conditions and requirements; and monitoring the site environment to verify that unanticipated or significant adverse effects are not occurring from past or continued use of the disposal site and that permit terms are met. The organization of this plan includes the six requirements for ocean disposal site management plans discussed in §102(c)(3) of the Act, as amended. These are:

1) consideration of the quantity of the material to be disposed of at the site, and the presence, nature and bioavailability of the contaminants in the material (section II.C);

2) a baseline assessment of conditions at the site (section III);

3) a program for monitoring the site (section IV);

4) special management conditions or practices to be implemented at each site that are necessary for protection of the environment (section V.A);

5) consideration of the anticipated use of the site over the long term, including the anticipated closure date for the site, if applicable, and any need for management of the site after closure (section VI); and

6) a schedule for review and revision of the plan (which shall not be reviewed and revised less frequently than 10 years after adoption of the plan, and every 10 years thereafter) (section VII).

This management plan must be consistent with the Federal Coastal Zone Management Act of 1972. This Act and the 1976 amendments enabled states to develop comprehensive management plans for their coastal regions (subject to Federal approval). For all projects located in Massachusetts' coastal zone that involve Federal action such as funding, permitting, or licensing (e.g., this management plan as well as any dredging and/or disposal activities at the MBDS), a Massachusetts Coastal Zone Management Consistency Review is required to ensure that actions proposed within the coastal zone are consistent with state coastal policies. Consistency certification was granted on December 27, 1996.

Although not formally required, EPA requested that NMFS conduct an Endangered Species Act Section 7 review for the above federal activity. NMFS concurred with EPA's determination that the activities proposed in this plan will not adversely affect threatened or endangered species or adversely modify critical habitat. In addition, because the actions recommended in this plan are in the vicinity of the Stellwagen Bank National Sanctuary, this plan must comply with section 304(e) of the MPRSA as amended, requiring consultation. EPA and NED consulted with Sanctuary staff as required under this act.

II. SITE BACKGROUND

A. Past Usage

The MBDS is a circular area 2 nautical miles (nm) in diameter located approximately 10 nm (approximately 12 miles) south-southeast of Gloucester, and 18 nm from the entrance to Boston Harbor centered at 42°-25.1'N and 70°-35.0'W **(Figure 1)**. It is located in about 90 meters of water in a deep basin called Stellwagen Basin, directly west of Stellwagen Bank, an underwater glacial moraine that rises to 50 meters of the surface within 3 nm of the disposal site, and because of its importance to fish and marine mammal habitat, a National Marine Sanctuary.

The MBDS overlaps with two other historical disposal sites: the Industrial Waste Site, or IWS, which was employed from the 1940s until 1976, and the interim MBDS, which was used from 1977 to 1992. The IWS is a 2 nm circular area centered at 42°-25.7'N, 70°-35.0'W and the interim MBDS is a two nautical mile diameter center circle centered exactly one nautical mile east, at 42°-25.7'N, 70°-34.0'W. In 1977, the EPA's ocean dumping regulations (40 CFR 228.12) established the interim dredged material disposal site (interim MBDS). In 1993, the EPA officially designated the MBDS, reconfiguring the boundaries to overlap with both the IWS and the interim MBDS, avoiding part of the IWS with a high concentration of industrial waste barrels (see below) and the newly designated Gerry Studds Stellwagen Bank National Marine Sanctuary. Since 1977, only dredged material has been disposed at the interim MBDS and the MBDS.

Historically, most dredged material was disposed at sites closer to shore than the MBDS, especially at the Boston Lightship Disposal Area, a site about 15 nmi from Boston, which was closed in 1976. Some dredged material that was considered contaminated (often without any chemical testing) was disposed in the vicinity of the deep water, offshore area termed the "Foul Area", the area including both the IWS and the interim MBDS. "Polluted spoils were barged to the "Foul Area", and relatively clean dredged spoils dumped at the '"Dumping Ground"' (Gilbert, 1975). This area was routinely dubbed the "Foul Area", because the material on the bottom "fouls" or damages commercial fishing nets. From the 1940s to 1977 dredged material, construction debris, barrelled industrial waste, encapsulated low-level radioactive waste, munitions, and intentionally sunken derelict vessels were dumped in the general area of the IWS (Hubbard et al., 1988, SAIC, 1994a and b, NOAA 1996 draft report). Up to 80,000 containers of hazardous and low level radioactive waste may have been disposed at this site (Wiley et al., 1992). The dumping of hazardous and low level radioactive waste was permitted by the Atomic Energy Commission and the Army Corps from 1953 to 1959, at which time the EPA issued permits for industrial waste only at the Foul Area. Most of the wastes appear to be in 55, 30 or 5 gallon drums, indicative of toxic or hazardous wastes, currently located in the northwest quadrant of the IWS (in an area around the coordinates 42°-26.4'N, 70°-35.4'W), or dispersed around the northern perimeter up to 0.5 nm outside the IWS (Wiley et al., 1992). Few drums are found away from the IWS. Dumping of industrial waste was terminated in 1976 and the IWS was formally de-designated on February 2, 1990.

Because of this area's past use as a dumping ground, the National Marine Fisheries Service (NMFS) closed the IWS to harvesting surf clam and ocean quahogs in 1980. In 1992, the Food and Drug Administration (FDA) and NMFS reissued this advisory, recommending a note be put on nautical charts, and advising all commercial and recreational fisherman to avoid harvesting bottom dwelling species from the area, including the MBDS (NOAA, 1996). There is some trawling activity in the area, but no evidence of otter trawl doors or foot rope sweep marks. In contrast, lobster traps are quite common in the area.

With designation in 1993, the boundary of the newly reconfigured MBDS avoids the area of the IWS that contains a high concentration of waste drums and the Gerry Studds Stellwagen Bank National Marine Sanctuary.

B. Buoy locations

According to records from the U.S. Coast Guard, before 1963, a disposal buoy was located at "an undisclosed location". From August, 1963 to January, 1975, the "A" (sometimes called "BFG") buoy, a conventionally moored buoy with a wide swath, was deployed by the U.S. Coast Guard at 42°-26.8'N and 70°-35.0'W (apparently outside of the IWS, and corresponding to the general area of most of the waste drums identified on the bottom). On January 29, 1975, the buoy was moved (south, about 1.1 nautical miles) to 42°-25.7'N and 70°-35.0'W to the center of the IWS. The disposal buoy remained here after the establishment of the interim dredged material disposal site in 1977. Thus, the disposal buoy remained at the western edge of the interim disposal site. Some dredged material was disposed in 1983 at a temporary buoy -- "Foul Area-South", or "FAS" -- located at 42°-25.39'N, 70°-34.54'W to test hopper dredging disposal.

In November 1985, a second disposal buoy, maintained by the Army Corps of Engineers NED, was deployed near its present location at 42°-25.1'N, 70°-34.45'W in the southwestern quadrant of the interim MBDS (Hubbard et al., 1988). (An April 1992 survey located the "MDA" buoy at exactly 42°-25.086'N, 70°-34.457'W.) From 1985 to about 1991, the "A" buoy was used as a backup disposal location. The new Corps buoy in 1985 is a taut-wired buoy which results in greater precision of dumping. It has been called, "DGD", "FDA" and is now named "MDA". Although the new MBDS was reconfigured in 1993, the buoy was not moved. It is located in the southeastern quadrant of the disposal site.

In addition to a sediment dredged material disposal buoy, a Rock Disposal Location (RDL) was established in 1991 specifically for disposal of rocks generated from downtown Boston's "Central Artery/Third Harbor Tunnel" and two other smaller projects. This location (which was marked only by coordinates, and not by a buoy) was in the northeast quadrant of the interim MBDS (about 500 meters outside of the new MBDS), on the slope of Stellwagen Bank at the coordinates 42°-26.5'N, 70°-34.0' at 50 m depth **(Figure 2)**. This location is now outside the current boundary of the MBDS and will not be used for future disposal.

C. Estimated quantity and quality of dredged material to be disposed

1. Dredged material quantity

Historically, the MBDS has been one of the most active disposal sites in New England, second only to the Central Long Island Sound disposal site. The dredged material has come from a number of harbors, rivers and channels from Gloucester to Plymouth, MA, many of which are industrialized. According to Corps records, Boston Harbor sediments have historically comprised about 67% of the disposed volume, South Shore sediments about 20%, and North Shore sediments about 13% (Hubbard et al., 1988).

From 1976 to 1994, the average annual disposal volume was 346,485 cubic meters **(Table 1)**. About 1.1 million cubic yards of sediment (primarily Boston Blue Clay) and blasted rocks from the Central Artery/Third Harbor Tunnel (now called the Ted Williams Tunnel) project were disposed at the MDA buoy and the Rock Disposal Location in 1992 and 1993. Some of the excavates from this project were disposed in a lined landfill on Spectacle Island. One other major project will likely create a substantial increase in disposal activity in the next 5 years. From 1997 to 2001, an additional 600,000 cubic yards of soft surface sediments and bottom clays from Fort Point Channel in downtown Boston will be dredged for the Central Artery project. Depending on the amount of mixing of surface sediments into the bottom clays during the stabilization process, about 350,000 cubic yards will be disposed at Spectacle Island, and the remaining clean material (mostly clays) will be disposed at the MBDS (Randall, personal communication). About 90,000 cubic yards of sediments determined unsuitable for disposal at the MBDS from the CA/THT project are contained in a lined facility on Governor's Island, adjacent to Logan Airport (Lipman, personal communication). None of these lined landfill facilities are expected to be available for disposal of other sediments in the future.

Second, the Boston Harbor Navigation Improvement Project will provide material for the MBDS from 1996 to 1998, if fully funded. Boston Harbor was last dredged in 1983. MassPort will dredge a total of 4.7 million cubic yards (mcy) including 1.7 mcy of uncontaminated parent (mostly clay) material, 88,000 cubic yards of rock for improvement dredging and 1.1 mcy of unconsolidated silty material for maintenance dredging and local berthing, which were deemed unsuitable for ocean disposal and will be isolated below approximately 1.8 mcy of sediments in the Chelsea and Mystic rivers (in-channel disposal; USACE, 1996). Over the next 50 years, it is estimated that the Corps and MassPort will need to dredge another 4.4 mcy of material from the main channel for future maintenance and 1.8 mcy from the tributaries (Lipman, personal communication).

Table 1. Volume (cubic meters) of dredged material disposed at the Massachusetts Bay Disposal Site on an annual basis from all sources in Massachusetts Bay. Sources:
1982-1994: Tom Fredette, personal communication, NED records
1976-1981: Hubbard et al., 1988

Year	Volume	Year	Volume
1976	239,746	1986	167,950
1977	38,400	1987	94,509
1978	25,320	1988	102,548
1979	70,273	1989	172,374
1980	11,552	1990	181,496
1981	241,004	1991	47,258
1982	678,260	1992	979,646
1983	216,320	1993	520,040
1984	222,730	1994	64,500
1985	135,524		

In 1994, the Cape Cod Bay disposal site (CCBDS) was identified by the Commonwealth of Massachusetts as an inland or nearshore Clean Water Act (CWA) Section 404 disposal site, but it is not anticipated that this site will reduce the projected volume at the MBDS. In 1994, the CCBDS received 135,598 cubic yards, all of it from Wellfleet Harbor. In the fall of 1996, Duxbury will dispose up to 300,000 cubic yards of material there. In both of these cases, these towns had not planned to barge sediments to the MBDS due to cost considerations and had not used the MBDS in the past. The Commonwealth of Massachusetts, with the NED, is currently engaging in a long term management study to estimate future use of the MBDS and the CCBDS (Babb-Brot, personal communication).

2. Dredged material quality and testing protocols

Sediments disposed at the MBDS are typically silt and sand, with occasional consolidated clay chunks (e.g. Boston Blue Clay), or rubble. For example, the majority of the material for the Boston Harbor dredging project is silt (60%) while the remainder (40%) is sand and gravel. In general, the dredged material is more sandy and heterogeneous than the ambient sediments (silt and clay) at the site, and in Stellwagen

Basin.

Surface sediments in Massachusetts harbors and estuaries proposed for future dredging sometimes exhibit high levels of contaminants. For example, Boston Harbor sediments are generally considered high in polycyclic aromatic hydrocarbons (PAHs), and chromium in Salem Sound sediments are among the highest recorded in the nation (Daskalakis and O'Connor, 1994). According to the EPA's National Sediment Inventory, most of the sediments tested from Gloucester to Plymouth have tested as moderately or highly likely to cause adverse effects to aquatic life or human health (EPA, 1996). Other studies have documented elevated concentrations in Boston Harbor and other harbors in Massachusetts Bay (Cahill and Imbalzano, 1991, Fore River Estuary Project, 1994, Hyland and Costa, 1995, Leo et al., 1993, MacDonald, 1991, Moore and Stegemen, 1995).

The dredged material to be disposed at the MBDS in the future will only be that material deemed suitable for ocean water disposal by both the Corps and EPA in accordance with established criteria ("ocean dumping criteria", 40 CFR Part 227). EPA implements its MPRSA statutory authority through the Ocean Dumping Regulations, 40 CFR 220-228. Correspondingly, the USACE's permit regulations are contained in 33 CFR 320-330 and 33 CFR 335-338. The NED and EPA use the procedural and technical guidance recommended by the "Green Book" or "Ocean Testing Manual" (Evaluation of Dredged Material Proposed for Ocean Disposal-Testing Manual, EPA/USACE, 1991) to evaluate the potential environmental effects of dredged material disposal in the ocean. A second manual, the "Regional Protocol",(Guidance for Performing Tests on Dredged Material to be Disposed in Open Waters, EPA-Region I/USACE-NED, 1989), adapts the national procedures to New England situations. It is currently in revision to reflect new guidance and will be available in 1997.

In practice, EPA Region 1 (New England) and the NED evaluate sediments in a tiered procedure **(Figure 3)**. Tier 1 is a data review to determine whether there is reason to believe the sediment is contaminated, and whether the sediment can satisfy exclusion criteria listed in 40 CFR 227.13(b). If chemical information is insufficient, the regional protocol requires bulk sediment analyses for grain size, total organic carbon (TOC), metals, total PCBs, pesticides, and a suite of priority polycyclic aromatic hydrocarbons (PAHs) according to EPA protocols (USEPA, 1986), or other national guidance (e.g. EPA/USACE, 1995). Additional chemical analytes may be required on a case-by-case basis. In Tier 2, EPA and NED evaluate the chemical data to determine whether marine water quality criteria are exceeded, or whether there is a potential for bioaccumulation (uptake of contaminants into an organism's tissues). Based upon the results of these analyses, EPA and NED determine the need for Tier 3 (biological evaluation) which requires that the proposed dredged material be tested for toxicity and bioaccumulation to appropriate marine species. If the test results indicate unacceptable toxicity compared to reference sediments, or bioaccumulation likely to cause adverse effects, then the proposed dredged material is not suitable for unconfined ocean disposal according to 40 CFR 227.6. Thus, dredged materials suitable for unconfined ocean disposal are not expected to cause unacceptable adverse effects to the marine environment.

D. Past Monitoring

Contemporary monitoring of the disposal area and the MBDS began with studies in the early 1970s by Thomas R. Gilbert, of the New England Aquarium for the Commonwealth of Massachusetts Division of Water Pollution Control (Gilbert, 1975). However, the main body of monitoring information stems from the Corps' Disposal Area Monitoring System (DAMOS). Begun in 1977, DAMOS is a multi-site oceanographic systematic monitoring program performed by a Corps contractor. It continues to be and will remain as the main vehicle for site monitoring. EPA Region I (New England) has also studied the site on a more limited basis. A fairly complete summary of these past monitoring efforts is provided in **Table 2**. In addition to the major findings of each survey, this table summarizes the methods used and parameters measured. Most of the studies have focused on the Interim MBDS and the IWS. Recently, studies have been performed on the new MBDS. Other researchers and agencies have investigated these areas on a more limited basis. They include investigations of the conditions of the hazardous wastes dumped at the IWS by EPA and National Oceanic and Atmospheric Administration (NOAA), and work performed by the U.S. Geological Survey (USGS) to map the bottom of Stellwagen Basin and Stellwagen Bank (Knebel and Circe, 1995; Valentine et al., 1996; NOAA, 1996). Results of some of these studies are presented in Section III.

Monitoring studies have employed a wide variety of assessment techniques. These include, among others, a) precision bathymetry (precise mapping of seafloor topography to determine formation of disposal mounds), b) sediment profile cameras to determine the nature and extent of dredged material on the bottom and a simple estimate of the biological community c) sediment chemistry sampling and analysis, d) water column sampling and analysis, e) tissue sampling and analysis, f) fishery resource assessments, g) submersible vehicle video analysis and h) benthic community analysis.

E. General impacts from disposal of dredged material

Overall, dredged material research performed by the Corps and EPA (on a national basis) has demonstrated that disposal-related impacts to the water column are of shorter duration and less concern than impacts to the sediment and benthos (Munns, et al., 1989; USACE, 1986). As a result, any impacts to sediment feeding organisms (e.g., clam worms and amphipods) will be longer lasting than for water filter-feeding organisms (e.g., mussels). Monitoring programs at the site have reflected these findings with an emphasis on benthic related impacts as opposed to water quality.

Dredged material released from a barge descends through the water as a somewhat cohesive dense fluid-like jet, entraining substantial volume of ambient water (called convective descent). Turbulence separates and suspends 3 to 5% of the total material, especially the fine grained sediments into the water column and transports it off-site (USACE, 1986; USEPA Region 1, 1992). The dense material hits the bottom and collapses, in a restricted area. The impact on the bottom creates a surge of sediment into the overlying water column, about 20% of the total water column depth (at MBDS, this would be about 15 meters), spreading several hundred meters radially and eventually settling within about 100 to 200 meters from the impact site. Levels of suspended solids above the bottom are usually temporarily elevated, even above those found in the surface plume.

In 1982, as part of the DAMOS program, researchers tested the transport of a plume from a disposal event at MBDS using a hopper dredge and a taut-wired buoy (SAIC, 1985). They found convective flow to the bottom removed most of the material from the water column within a few minutes. Immediately after disposal, 750 mg/liter of suspended solids was observed in a surface water plume, but decreased to 5 to 12 mg/liter after about 40 minutes of lateral transport (ambient concentration = about 1 mg/liter). Characterizing the plume transport with acoustic devices resulted in an estimate that about 3% of the material had been dispersed in the near surface water column, away from the site. However, bottom suspended solids concentrations from the surge were not measured.

Results of modelling the disposal of material from the Central Artery/Third Harbor Tunnel project concluded that the surge would resuspend sediments 15 feet (5 meters) above the bottom (NMFS, 1991), but settling would occur within three hours. The maximum increase of suspended solids near the bottom would be about 929 mg/liter, and the maximum increase at the *disposal site boundary* would be about 2 mg/l. Dispersal of material from the surface plume 2500 meters away would result in net deposition of sand and silt to the bottom of a virtually undetectable amount. A 3000 cubic meter dump would result in net deposition to the bottom of about 0.003 mm. Finer particles would stay suspended in the water column and be transported off site, but temporary increases in contaminant concentrations clearly would not exceed water quality criteria.

EPA Region 1 modeled the disposal of sediments for the Final Environmental Impact Statement using the Corps' ADDAMS (Automated Dredging and Disposal alternatives Management System) model (USEPA Region 1, 1992). This model, which used conservative assumptions, predicted no exceedances of water quality criteria after the allowed four hour mixing time within the site, providing further evidence that disposal of dredged material does not cause water column impacts to Massachusetts

Bay.

Thus, this monitoring plan will focus on bottom resources affected by the direct disposal of dredged material hitting the bottom, and the spreading of dredged material radially beyond the immediate point of impact.

III. BASELINE SITE CHARACTERISTICS

A. Physical Site Characteristics

Much of the information in this section comes from studies conducted by SAIC from 1985 to 1987 for the NED for the site evaluation studies (Hubbard et al., 1988). Recent studies conducted by the USGS, Massachusetts Bays Program (MBP) and the Massachusetts Water Resources Authority (MWRA) have confirmed and supplemented many of these observations.

1. Physical oceanography

The area near the MBDS receives surface currents from the Gulf of Maine, a weak coastal current which enters Massachusetts Bay over a sill between Stellwagen Bank and Cape Ann. From May through October, the water column is typically stratified, with the pycnocline located at approximately 15 to 20 meters. The greatest stratification is usually in August or September, but the stratification usually breaks down through vertical mixing during October as the winds increase, and the water column is typically isothermal from November until April. Bottom water temperatures at the MBDS vary from about 3 to 5 °C.

During the summer, mixing is generally suppressed across the pycnocline and little exchange of water occurs between the upper and lower layers, although the action of internal waves developed over Stellwagen Bank provides some mixing. Stellwagen Bank blocks the exchange of bottom water with the Gulf of Maine, so most of the water in Stellwagen Basin probably derives from Massachusetts Bay.

Surface currents generally exhibit velocities of 10 to 20 cm/sec, dominated by the northeast to southwest tidal flow in this area. The ebb and flow of the tides is not easily detected in bottom waters, 80 to 90 meters below the surface. Bottom waters have a slight east to west flow orientation during the fall, and a nearly rotational flow during winter. Average bottom currents are generally low, typically less than 10 cm/sec. Flow measurements taken in 1987 showed current velocities less than 4 cm/sec for over 85% of the record.

Although recent weather patterns do not attest to this, severe northeasters or hurricanes of the intensity (greater than 45 mph winds from the east) expected to resuspend bottom sediments in the area can be expected about once every four years. In 1985 and 1986, bottom currents ranged from 4 to 7 cm/sec, except prior to Hurricane Gloria in September 1985 when oscillatory currents on the order of 20 cm/sec were noted. During strong northeast storms, in winds greater than 45 mph, currents generally, though not always, can increase in a southerly and easterly direction to speeds of 30 cm/sec, as a result of back flow from the generally westward (from the east) surface flow. EPA Region 1 (1989) stated that storm-induced flow is expected to transport sediments to the west and southwest. However, based on a three-dimensional hydrodynamic model of Massachusetts Bay developed by the USGS, in response to a 35 mph wind from the northeast, bottom currents would be expected to flow to the north and east at less than 10 cm/second (Signell, personal communication). Although coarse grained sands might be transported in this direction, fine grained material could be resuspended into the water column where it could be transported by midwater and surface currents in a variety of directions. In sum, dredged material could be expected to be transported off disposal mounds in probably all directions.

2. Bathymetry

The MBDS is situated in the northwestern corner of Stellwagen Basin, a large depression within Massachusetts Bay ranging from 80 to 100 meters depth, and separated from the Gulf of Maine by Stellwagen Bank, a sand and gravel underwater shelf which rises to the east to within 50 meters of the surface. Glacial events 14,000 to 50,000 years ago scoured the seafloor and eventually deposited till and outwash (pulverized rock, gravel and sand) which now form Cape Cod, Stellwagen Bank, and other prominent features of the land and seascape. The detailed bathymetry within the MBDS is shown in **Figure 4**. In general, the area is a smooth generally featureless area with depths ranging from 82 to 92 meters. There is a slight trough running northwest to southeast along the length of the site. A small circular depression in the northeast quadrant of the site with maximum depths of greater than 90 meters, and a glacial knoll at the northern boundary break up the relatively dull landscape. Within 1000 meters of the northeast edge are the steep flanks of Stellwagen Bank. This slope is the area where rock was disposed from the CA/THT project (the RDL).

3. Benthic environment and sedimentology

Because of slow current speeds and bottom topography, the MBDS is located in a depositional environment and is subject to accumulation of fine grained silt and clay particles. The most common grain size is silty sand, with a phi size of about 4 to 5, but ranging anywhere between 3 to 7. Sediment accumulation rates are about 0.1 to 0.2 cm/year and sediment profiles indicate accumulation of anthropogenic contaminants from distant or regional sources (Wade et al., 1989). Up until 1985, disposal of dredged material did not create any visible mounds at the site. However, dredged material could be detected by a variety of techniques such as side scan sonar, sediment profile imaging and grab sampling. Side scan sonar and sediment profile imaging can detect areas of past and recent dredged material disposal, indicated by either high reflectivity (clumped deposits) or sandier sediments overlying finer sediments. A new type of sediment acoustic characterization system (SACS), which utilizes low frequencies can penetrate sediments further, and detect presence of relic dredged material was employed in 1993, observing a thin layer of fine grained sediments (less than 6 cm) accumulating over historical dredged material throughout the new MBDS. Based on work from the 1980s and more recently, the new MBDS can be characterized into 4 major sediment texture groups:

South: silty undisturbed sediments;

Northeast: silty dredged material sediments extending beyond the disposal buoys, with dredged material accumulating up to 15 cm above the bottom. Dredged material found over a large area, up to 1000 meters north, and even to 1 nautical mile away from the disposal buoys, in all directions;

Disposal mounds: two heterogeneous mounds including sandy sediments, or cohesive clay clumps up to 7 meters above the bottom; and

North: silty sediments with scattered industrial waste barrels and other debris.

Trawl marks have been observed in the soft sediments by side scan sonar in the 1985 surveys. A side scan sonar and video survey by the USGS in 1995 describes the seafloor as a "soft watery mud represented by low backscatter" (Valentine et al., 1996). However, within the site and general area, there are many observations of knolls, sunken vessels, rock debris, dredged material, anchor scars, possible exploded munitions, and other man-made objects. The knolls orient in a NW-SE direction reflecting movement of glacial ice, in various stages of burial in mud, rising up to 15 meters above the seafloor and covered with a thin veneer of mud. One such knoll is located at the northern edge of the new MBDS. This feature potentially provides habitat for groundfish, shrimp and burrowing organisms. In contrast, Stellwagen Bank, rising 30 to 40 meters above the basin, is characterized by hard gravelly sand with scattered cobbles and boulders supporting anenomes, sponges and other hard bottom attached organisms.

The USGS has reported finding glass shards, metal fragments, slag, old pill bottles and leather gasket material in sediments collected from western Massachusetts Bay (Butman et al., 1992). Descriptions of the IWS indicate that the basin is a former dumping ground for a variety of hazardous and inert material. And, because much of Massachusetts Bay and Stellwagen Bank are fished using bottom gear, otter trawls and lobster traps, one could characterize the environment in and around the MBDS as permanently altered, or constantly disturbed.

B. Chemical Site Characteristics

1. Water quality

Salinity values at the MBDS generally range between 28 and 33 parts per thousand (o/oo), depending on season and depth, reflecting the influences of coastal runoff from Maine, New Hampshire and Massachusetts rivers, and continental shelf waters from the Gulf of Maine. Bottom water salinities are fairly stable, varying only slightly, at around 32 parts per thousand (o/oo). Near-bottom dissolved oxygen concentrations in the site vicinity typically vary from 6 to 12 mg/l, with minima occurring in September or October (Hubbard et al. 1988, Geyer et al., 1992).

The water at the disposal site is generally very low in suspended solids. Recent measurements of suspended solids indicate values ranging from 0.2 to 3 mg/liter, (at the subsurface chlorophyll maxima, near the pycnocline), with most observations below 1 mg/liter. In contrast, suspended solids measured in Boston Harbor routinely exceed 2 mg/liter ranging from 0.1 to 25 mg/liter (Robinson et al., 1990). MBDS bottom waters sometimes exhibit elevated suspended solids levels (up to 2 mg/liter), probably due to resuspension of bottom sediments (Geyer et al., 1992). Levels of trace metals in the water column are also generally very low. Recent measurements performed for EPA Region 1 in 1992 found very low levels of trace metals and organics compounds in the water column (Battelle, 1992). Stations at the MBDS did not differ significantly from a reference site about 23 nautical miles east, in the Gulf of Maine **(Table 3)**. Individual low molecular weight PAHs were detected at very low concentrations and high molecular weight PAHs were rarely detected. The sum of 16 priority pollutant PAHs ranged from 51 – 97 ng/liter at the MBDS and 41 – 58 at the Gulf of Maine station. Total PCBs and pesticides were consistently below detection limits (2 to 10 ng/liter) at both the MBDS and the Gulf of Maine stations.

Table 3. Range of concentrations of trace metals and PAHs (micrograms per liter, or parts per billion, ppb) in whole (dissolved plus particulate) water samples collected at the interim MBDS and the Gulf of Maine (Battelle, 1992), and compared to a range of values from two stations in Massachusetts Bay (Battelle, 1987) and EPA Chronic Water Quality Criteria values. Samples were collected from a variety of depths.

	Mass Bay	MBDS	GOM	Water Quality Criteria
Arsenic	0.41 – 0.55	1.14 – 1.29	1.15 – 1.25	36
Cadmium	0.024 – 0.031	0.020 – 0.033	0.025 – 0.031	9.3
Chromium	0.26 – 0.42	0.099 – 0.617	0.121 – 0.117	50
Copper	0.33 – 0.52	0.163 – 0.301	0.105 – 0.211	2.9
Lead	0.078 – 0.189	0.029 – 0.190	0.054 – 0.133	8.5
Mercury	0.0018 – 0.0041	0.0004 – 0.0014	0.0006 – 0.0007	0.025
Nickel	0.35 – 1.1	0.262 – 1.604	0.323 – 0.538	8.3
Zinc	0.73 – 1.60	0.118 – 0.573	0.082 – 0.325	86

2. Sediment quality

Marine sediments in general are characterized by a redox potential discontinuity (RPD) layer which denotes the depth of sediment where chemical reduction/oxidation (redox) potentials change from positive to negative. The sediments above this zone are generally aerobic and supportive of diverse benthic organisms, while those below are generally anaerobic and less diverse. At the MBDS, sediment unaffected by dredged material, apparent RPD depths (measured using the sediment profile camera) have ranged from 2 to 7 cm with a majority in the 4 to 6 cm range (SAIC, 1990a). Areas with freshly disposed dredged material typically exhibit lower apparent RPD depths (0.5 to 2 cm) than fully recolonized mounds or reference areas. Recent measurements of TOC on dredged material mounds, and in the vicinity of the MBDS usually range from 0.5% to 2.5%, with a mean of about 1.0% (SAIC, 1990b, SAIC, 1994a). Measurements in 1985 and 1986 in and out of the MDA buoy area and in reference areas exhibited higher levels, ranging from 2.5 to 3.2% (Hubbard et al., 1988).

Background sediment contaminant concentrations are generally low, but detectable (**Table 4**). Most contaminants are at or below NOAA's "Effects Range-Low" levels -- a level below which toxicological effects are rarely observed (Long et al., 1995). Because the MBDS is located in a settling basin, sediments accumulate particle-derived contaminants from regional sources. Vertical sediment profiles reflect this phenomenon of the long-term history of contamination in Massachusetts Bay (Wade et al., 1989). Detectable levels of contaminants such as PCBs and DDTs were found up to 200 cm below the surface sediment in Stellwagen Basin cores, indicating affinity for fine particles, regional sources and persistence of these, now banned, contaminants. A detailed discussion of sediment chemistry at disposal sites and reference areas is included in **Section E.**

Table 4. Levels of selected contaminants in MBDS reference sediments (mean plus 2 standard deviations; SAIC, 1995b) compared to estuarine sediment quality concentration ranges proposed by NOAA (Long et al., 1995)[1]. Metals -- parts per million (ppm) dry weight; PCBs, DDTs, PAHs -- parts per billion (ppb) dry weight. Sum of PAHs may differ based on which individual PAHs measured.

	MBDS Ref	Effects Range	
	Mean+2SD	Low	Medium
Arsenic	28.7	8.2	70
Cadmium	2.74	1.2	9.6
Chromium	151.6	81	370
Copper	31.7	34	270
Lead	66.3	46.7	218
Mercury	0.277	0.15	0.71
Nickel	40.5	20.9	51.6
Zinc	146	150	410
LMW PAHs	449	552	3160
HMW PAHs	2730	1700	9600
Total PAHs	3080	4022	44792

[1] *These values are not used for regulatory purposes.*

C. Biological Site Characteristics

1. Benthos

At disposal sites in New England, benthic infauna generally recolonize fresh dredged material in a relatively predictable sequence, characterized by three stages of succession (Rhoads and Germano, 1986). The first stage (Stage I) is dominated by small, opportunistic, tube-forming, capitellid, spionid, and paraonid polychaetes or oligochaetes which rapidly (i.e., within 1-2 weeks) colonize new disposal mounds and which do not penetrate into the sediments very deeply. These organisms are thought to be recruited to the new habitat from off the disposal mound. Stage II is dominated by deeper penetrating species, which include tubicolous amphipods (e.g., Ampelisca abdita), and molluscs, typically occurring 3-6 months after disposal has ceased. These taxa represent a more transitional stage, and they may or may not hold permanent positions in the long term benthic community structure. Stage III animals represent an "equilibrium", or "mature" level, typified by deeper-dwelling, head-down deposit feeding species [e.g., maldanid (Clymenella zonalis) and pectinid polychaetes, holothurians, and nuculid bivalves (Yoldia spp.), and predatory polychaetes, such as Nephtys incisa]. This stage can also occur during the first year after dumping, but additional time for larval recruitment from off-site locations may be required. Some head-down deposit feeders are thought to be capable of migrating up through the fresh dredged material after a disposal event to maintain position in the sediment. It is not uncommon to find more than one successional stage present at any one location (e.g., a Stage I community coexisting above a Stage III community). These communities can be "remotely" observed with a sediment profile camera, but more accurate community analysis requires sieving, sorting and identification of all taxa in a grab sample.

Based on samples in 1985 and 1986, the benthic infauna in the soft undisturbed sediments near the disposal mounds are dominated by spionid (e.g. Spio limicola), paraonid (e.g. Levinsenia=Paraonis gracilis) and capitellid (e.g. Heteromastus filiformis) polychaetes, typical of Massachusetts Bay and Stellwagen Basin (Hubbard et al., 1988). These species may be categorized as primarily Stage I or Stage II organisms. Taxa associated with undisturbed mud bottom sediments include the bivalve Yoldia and the holothurian Molpadia, typical large stage III organisms, occurring primarily from 2 to 15 cm depth.

In contrast, the benthic community on dredged material exhibited higher relative abundance of oligochaetes, and other small opportunistic spionid polychaetes, reflecting the nature of dredged material as a disturbed habitat with, sometimes, high organic content. The sediments affected by dredged material were dominated by individuals in the surface 0 to 5 cm.

A station outside the influence of dredged material, but still within the MBDS, appears to be dominated by organisms of intermediate size and occurring at intermediate depths (Lunz, 1988). Although not formally calculated at the MBDS, species diversity at sites affected by dredged material appears to be generally less than at undisturbed sites.

Sandy sediments to the northeast of the MBDS at the rise of Stellwagen Bank, are dominated by a totally different fauna, such as suspension feeding bivalves and hard bottom species.

No benthic community analyses have been conducted at MBDS since 1986. However, community analyses at muddy stations greater than 60 meters near the MBDS collected for the MWRA monitoring program in May and August 1992 found the dominant infaunal taxa were spionid polychaetes (Spio limicola -- composing 20 to 60% of the community in some samples), paraonid polychaetes (Levinsenia gracilis and Aricidea quadrilogata), capitellid polychaetes Mediomastus californiensis, cirratulid polychaetes Chaetozone and the oligochaete Tubificoides apectinatus. Deposit-feeding bivalves such as Nucula delphinodonta were also found. Although not dominant taxa, indications of stage 3 organisms were observed with a sediment profile camera at these stations.

In sum, based primarily on sediment profile camera imaging, community succession in areas affected by dredged material within the MBDS appears to be occurring, although traditional benthic community analyses of recolonized dredged material has not been conducted.

2. Fisheries

The Gulf of Maine supports over 200 resident and migratory species of fish. Although considered overexploited by NMFS, the predominant fishery in the disposal site area are groundfish, flatfish or other bottom dwelling fish, harvested by trawling gear **(Table 5)**. The American plaice, or dab, is consistently found as the most common bottom fish in the Stellwagen Basin area in surveys by MA Division of Marine Fisheries (MA DMF) and National Marine Fisheries Service (NMFS), and in surveys specifically targeted at the disposal site (e.g. Lunz, 1985). This fish is probably the most common fish caught in deep water (>55 m) trawls in the Gulf of Maine (Hubbard et al., 1988). In 1992, landings of this fish in New England were about 6700 metric tons, approximately one third of the landings in the early 1980s (NMFS, 1995). The other most abundant fish species is the witch flounder, or gray sole.

The most important and abundant shellfish in the vicinity of the disposal site is the American lobster. Lobster gear have been observed in and around the disposal site boundaries, and are probably more prevalent at the site in late fall, winter and spring. Landings of American lobster in Massachusetts alone averaged about 6,800 metric tons in 1993 and 1994. The ocean quahog is also commercially harvested in Massachusetts Bay, and is known to occur in the MBDS area.

Table 5. Commercially and recreationally important finfish and shellfish observed in the vicinity of the MBDS. Sources: Hubbard et al., 1988, NMFS, 1995.

Bottom-dwelling fish	
American plaice	Hippoglossoides platessoides
Atlantic cod	Gadus morhua
Yellowtail flounder	Limanda ferruginea
Witch flounder	Glyptocephalus cynoglossus
Ocean pout (hardbottom)	Macrozoarces americanus
Red hake	Urophycis chuss
Silver hake	Merluccius bilinearis
Longhorn sculpin	Myoxocephalus octodecimspinosus
Sea raven	Hemitripterus americanus
Winter flounder	Pseudopleuronectes americanus
Haddock	Melanogrammus aeglefinus
Goosefish	Lophius americanus
Thorny skate	Raja radiata
Pollock	Pollachius virens
White hake	Urophycis tenuis
Redfish (hardbottom)	Sebastes fasciatus
Pelagic or semi-demersal fish	
Spiny dogfish	Squalus acanthius
Sandlance	Ammodytes americanus
Atlantic herring	Clupea harengus
Atlantic menhaden	Brevoortia tyrannus
Shellfish	
American lobster	Homarus americanus
Sea scallop	Placopecten magellanicus
Longfin squid	Loligo pealei
Ocean quahog	Arctica islandica
Northern shrimp	Pandalus borealis

American plaice and witch flounder feed primarily on small prey, such as brittle stars, amphipods, polychaetes, pandalid shrimp, and to a lesser extent, bivalve molluscs. Observations in 1985 indicate that fewer fish inhabit the disposal site near the dredged material and of those present, are generally smaller than those found away from the disposal area (Hubbard et al., 1988). In addition, for American plaice and witch flounder, larger fish tend to feed on larger prey; fish inhabiting the disposal areas apparently fed on smaller prey. Continuous dredged material disposal appears to maintain habitat for small dab and sole by maintaining a disturbed condition and increasing the abundance of small infauna in surface sediments.

Although not caught commercially in high quantities, the semi-demersal sandlance is important as food for marine mammals, such as the humpback and fin whales. Adult sandlance occur primarily in sandier sediments, preferring the sloping, gravel bottom edges of Stellwagen Bank, but larval and adult fish have been observed by submersible vehicles near the soft sediments of the MBDS (Hubbard et al., 1988; NMFS, 1991).

Peak concentrations of planktonic larval fish eggs probably occur in the area in late spring and early summer. Larval abundance peaks in spring and summer.

3. Marine mammals and endangered species

Several species of marine mammals regularly frequent the deeper open waters of Massachusetts and Cape Cod Bays as well as Stellwagen Bank, and there are rare sightings of other species **(Table 6)**. Of these species, the National Marine Fisheries Service believes the Fin, Sei, Humpback, and Right whales, and the Leatherback sea turtle deserve special attention because they occur in and around the MBDS (NMFS, 1991).

Cape Cod Bay and the southern portion of Stellwagen Bank have been designated by NMFS as critical habitat for the endangered North Atlantic right whale Eubalaena glacialis. These whales enter the bay in late winter and spring and feed on the large concentrations of calanoid copepods present at that time. Sei whales also feed on calanoids and their abundance often corresponds with the Right whale. Sei whales have been observed feeding in the deep waters of Stellwagen Basin (NMFS, 1991).

Humpback and Fin whales are piscivirous, feeding primarily on sandlance, but also on herring, Atlantic mackerel, and euphausiid shrimp (krill). Juvenile Humpbacks have been observed feeding at depth in Stellwagen Basin, although this area is not considered the preferred feeding habitat (NMFS, 1991). Occurrence of these species in this area is limited to spring to late summer, and often corresponds to abundance of sandlance. Sandlance and whale abundance in this area varies from year to year. In 1994 and 1995, abundance declined, but sightings have rebounded in 1996. These species have also been observed more recently to the north, in Jeffrey's Ledge, where abundant stocks of herring are present.

Table 6. Visiting or resident marine mammals, turtles, fish and birds in Massachusetts Bays including endangered (**) and threatened (*) species (Source: NOAA, 1991; NMFS, 1991).

Humpback whale (**)
North Atlantic Right whale (**)
Fin whale (**)
Sei whale (**)
Blue whale (**)
Leatherback sea turtle (**)
Kemp's Ridley sea turtle (**)
Green sea turtle (**)
Shortnose sturgeon (**)
Roseate tern (**)
Loggerhead sea turtle (*)
Piping plover (*)
Minke whale
Pilot whale
Orca whale
White-sided dolphin
White-beaked dolphin
Harbor porpoise (proposed to be listed)
Bottle-nose dolphin
Common dolphin
Striped dolphin
Grampus dolphin
Harbor seal
Grey seal

D. Tissue burdens of toxicants

Tissue burdens for metals, PCBs, pesticides and PAHs and other toxicants (e.g. radionuclides) were assessed in American plaice, winter flounder, lobster, sea scallop and ocean quahog collected from the MBDS in 1985 and most recently in 1991 (Gardner and Pruell, 1991) and 1992 (NOAA, 1996; including the IWS). Results of the 1991 surveys are also presented in the Final Environmental Impact Statement (FEIS) for the designation of the new MBDS (US EPA Region1, 1992). In general, the results show low but detectable levels of contaminants in fish and shellfish tissues **(Table 7)**. Collections of fish and shellfish tissue from the IWS also exhibited concentrations within ranges for coastal Massachusetts and below levels of concern for public health (NOAA, 1996). However, PAHs and PCBs were elevated in the tomalley (not the meat) of lobster collected from the IWS. It is not known whether these tissue levels have any effects on the health of the individual organisms, or on local populations.

Radionuclides were not found above background levels in any organisms at the IWS.

Tissue burdens from marine mammals have also been collected in the area. These are currently being analyzed by U.S. EPA Environmental Health and Effects Research Laboratory in Narragansett, and results are not available at this time.

E. Disposal mound and Reference station characteristics

1. "A" buoy/Coast Guard buoy

This buoy site is located in the north of the site, in an area of gently sloping bottom on the northern margin of the small circular depression. Because this buoy was not a taut-wired buoy, and because dumping practices were not as rigorously monitored in the past, the areal extent of detectable historic deposits of dredged material appears to be an area almost one quarter the size of the disposal site, mostly to the west of the buoy location **(Figure 5)**. Other recent observations using side-scan sonar characterize this area as an irregularly shaped elliptical "subtle" mound, with the longest dimension in the northeast to southwest direction of 1000 meters (Valentine et al., 1996).

In 1983, this buoy area was surveyed by precision bathymetry, side scan sonar, and sediment grab samples to determine the fate of Boston Harbor dredged material from the previous year's disposal (SAIC, 1985). Bathymetry could not pick up formation of a disposal mound, but side scan sonar could detect the areal extent of disposal, which was estimated as about 25 cm thick. The signature of sediments, elevated in trace metals (copper, lead, mercury and zinc) from Boston Inner Harbor, were clearly distributed up to 700 meters away from a temporary taut-wire disposal buoy set up specifically for that disposal season. Sediment samples two months later documented the approximate extent of the disposal event to within about 500 meters of the buoy.

The first sediment profile camera survey at MBDS was conducted in October 1984 after two disposal operations totalling 95,000 cubic yards (SAIC, 1985). The presence of dredged material 11 to 19 cm thick was detected near the "A" buoy. Further away from the buoy, especially in stations east of the buoy, little dredged material was detected (although few stations were measured to the west of the buoy). Most of the dredged material was apparently similar to the ambient silty clay sediments with a high (about 7 cm) apparent RPD layer in both dredged material and nearby sediments leading scientists to hypothesize that the dredged material was not organically enriched. Many of the dredged material stations photographs indicated the presence of both stage I (colonizing) and stage III (head-down deposit feeders) polychaetes. The stage III worms may have burrowed up through the sediment or laterally from adjacent sites to reestablish their positions. An active bottom community apparently recolonized and bioturbated the sediments, only 3 to 6 weeks after disposal.

Based on sediment profile camera surveys in June and September of 1985, dredged material extended up to 1 nautical mile away from the buoy in all directions, and up to 18 to 20 cm thick in some places, with no obvious disposal mound (Hubbard et al., 1988). It was probably best described as a "pancake". Dredged material appeared to be relatively stable, because it was persistently detected in similar spots, and the areal coverage of dredged deposits was not increasing.

After 1985, this buoy site was no longer used on a regular basis. In November 1988 to January 1989, this area was surveyed to determine whether recolonization of the historically disposed dredged material had occurred (SAIC, 1990a). Benthic recovery appeared to be occurring, as apparent RPD depths ranged from 2 to 7 cm, and Stage III organisms were prevalent throughout the site, similar to undisturbed sediments.

In June 1989, sediment quality at sites near the "A" buoy, and the IWS indicated some elevated levels of trace metals, especially copper, but most were similar to reference stations (SAIC, 1994a). A station labelled "12-3", west of the buoy, often exhibited the highest values, especially for total, high molecular weight, and individual PAHs, although still below current EPA draft sediment quality criteria, after normalization for TOC **(Figure 6)**. Few pesticides and PCBs were detected compared to measurements made in 1985. A sediment profile camera survey in August 1994 indicated the presence of stage 3 organisms along transects radiating from the 12-3 station, although some of the sediment appeared to have lower apparent RPD depths, below 4 cm. Thus, although this area contains elevated levels of certain chemical contaminants, benthic recolonization appears to be occurring (SAIC, 1996b).

Because of the historical contamination at this site, in September 1994 EPA collected sediments from the "12-3" area and from a site within the IWS and a reference station to test for bioaccumulation and toxicity using methodologies recommended for testing dredged material for ocean disposal (Metcalf & Eddy, 1995). Concentrations of trace metals, PCBs, DDTs and PAHs in sediments at "12-3" and the IWS were elevated above the 1994 reference station **(Table 8)**. Results were consistent with prior results showing elevated levels of PAHs near buoy "A" **(Table 9; Figure 7)**. There was evidence of statistically significant bioaccumulation of individual PAHs, PCB congeners, DDTs and trace metals into two test species -- the bivalve Macoma, and the polychaete Nereis **(Tables 10 and 11)**. Levels of bioaccumulation were usually lower than tissue burdens in another polychaete (Nephtys) collected from near the "MDA" buoy during the site evaluation studies **(Table 12)**. In addition, the sediments were not acutely toxic to two species of amphipods, Ampelisca and Leptocheirus **(Figure 8)**. In sum, it appears that contaminants in these sediments exhibit the potential to bioaccumulate although they do not appear to be causing unacceptable impacts at or beyond the mound (see data on fish tissue concentrations in IWS section).

2. "MDA" Buoy

This buoy was established in November 1985 and has been named DGD, FDA, and most recently, MDA. A temporary experimental buoy, the FAS buoy, was located nearby in 1983, to determine the fate of disposal of dredged material. The depths in this area range from 87 to 89 meters and the buoy location lies in a trough running northwest to southeast, just to the southwest of Stellwagen Bank **(see Figure 4)**.

Sediment profile camera and bathymetric surveys conducted from 1986 to 1992 consistently found that this mound continuously grew vertically, and to a small degree, laterally. In January 1987, the sediment profile camera survey indicated a 20 to 50 cm thick "pancake-like" deposit developed with a radius of about 500 meters. Areal coverage of the deposit was estimated as 792,400 square meters. Disposal events in 1988 had formed a mound characterized by a "chaotic mixture of rubble, sand and clay clasts" (SAIC, 1990b). By August 1990, when compared with predisposal bathymetry, a definite mound measuring 0.8 m in (maximum) height and 420 m in diameter, was centered just to the east of the buoy (SAIC, 1994b). Dredged material extended about 400 to 500 meters on all sides, with up to 800 meters to the west of the buoy, and the areal coverage was estimated as 661,000 square meters. The depth of fresh dredged material, which was sandier than the ambient sediment, was about 10 to 20 cm at the flanks. Stations near the mound did not generally exhibit signs of Stage III infauna, and apparent RPDs were also very low, 1 to 3 cm. In contrast, RPD depths ranged from 5 to 7 cm at moderately or unimpacted stations away from the developing mound.

By 1992, two distinct mounds had formed west of the buoy, dominated by the Boston Blue Clay deposited from the CA/THT project (Wiley and Charles, 1995). This is a very consolidated and primarily homogeneous greenish gray clay. The maximum height of the mound was 2 meters with an area extending in an ellipse 200 to 400 meters from buoy. These surveys were conducted after two major storms in 1991 (Hurricane Bob and Halloween Nor'easter), and although most of the Boston Blue Clay was disposed after the storm events, the present mound appeared to be persistent, because relic dredged material can still be detected up to 900 m west of the buoy. The storms may have resuspended and redistributed some relic dredged material to the west as predicted (EPA Region 1, 1989). Stage III taxa were present throughout, except at the center of the mound, where only Stage I occurred on fresh dredged material.

Recent observations after a high level of activity in 1992 and 1993 from the CA/THT project indicate that the dredged material mound is smaller, steeper and better defined than the "A" buoy "mound", extending approximately 6 to 7 meters above the seabed to a maximum depth of about 80 meters (Valentine et al., 1996; DeAngelo and

Murray, 1996). The longest dimension is approximately 800 meters in an E-W direction, but is generally a 500 x 250 meter irregularly shaped mound. It is more highly reflective by side scan sonar, indicating the surface has not yet been colonized as much as the "A" buoy mound. Anchor scars, from the taut-wire buoys, some 600 meters apart, can also be observed in the side scan sonar traces. The most fresh dredged material appears to be primarily fine grained sediment with about 15% sand. Disposal appears to be occurring within 200 meters of the buoy, so lateral extent of the mound is limited. Some stations in 1993 near the mound exhibited signs of Stage II amphipods but most stations exhibited evidence of both Stage I and Stage III fauna.

The chemical quality of the dredged material at this mound has been measured on a number of occasions, and summarized in SAIC, 1990b, SAIC, 1994a, and DeAngelo and Murray, 1996 **(Table 9)**. In general, contaminant levels at and around the mound are only slightly elevated above background or reference stations. For example, total PCBs since 1985 have remained below 400 ppb. Evaluation of PAH data has been difficult because of high detection limits. Nevertheless, indications are that levels at this mound are more similar to reference station levels than to the higher levels reported at station '12-3' west of buoy "A". Compared to regional sediment quality, mean levels of contaminants from most of the northern and central area of the new MBDS are similar to NOAA's National Status and Trend mean data, and intermediate between clean (Cape Ann, Duxbury) and contaminated (Quincy Bay, Salem Harbor) sites in Massachusetts Bay (SAIC, 1994a).

In 1987, body burdens in Nephtys incisa (the red-lined worm), were measured (Hubbard et al., 1988). In general, no correlation was found between sediment contamination levels and tissue concentrations for most compounds. However, despite relatively high detection limits, maximum PAH levels were found in both sediments and animals at the disposal mound with fresh dredged material. It is not known whether these levels could cause adverse effects to individuals or populations of these species.

3. Reference areas (or stations)

Reference areas, or stations, are important for comparison to conditions at the disposal mounds, and are used in the testing protocols (see section II.C.2). Four reference stations have been sampled frequently since 1985 **(Table 13)**. "Ref-A" is the current reference station used in the biological testing protocols.

In general, these areas appear to be free of contaminants, and exhibit healthy benthic communities representative of Stellwagen Basin. Dredged material at these stations has never been detected by sediment profile camera surveys, apparent RPDs are usually around 5 to 7, and the benthic community, as assessed by the sediment profile imaging only, is usually healthy, with Stage I and Stage III organisms present. However, some variations exist, possibly due to seasonal effects.

Concentrations of contaminants in the sediments at all the reference areas are generally lower than at the disposal mounds. At stations 18-17 and FG-23, concentrations have appeared to remain relatively stable over time from 1985 to present (SAIC, 1994a; **Table 9**). However, concerns for potential of impacts to station 18-17 (high TOC content, slightly elevated contaminants, lack of Stage III fauna, and proximity to the mound) prompted moving the reference area to a new location, "REF-A", when the new MBDS was designated in 1993. Recent sediment profile images from this new station indicate occasional low apparent RPD depths to 1 cm, so further monitoring of the "REF-A" area is warranted.

4. Rock disposal location (RDL)

The RDL was established in 1991 as the point location for disposal of rocks from the CA/THT project. It is located on the slope of Stellwagen Bank in the northeast quadrant of the interim MBDS in an area of gravel, sand and cobble **(see Figure 2)**. Rock debris primarily lies within a 200 meter radius of the location, but there is some evidence (from side scan sonar and video images) of debris to the east and west, possibly indicating poor positional control (Valentine et al., 1996). No buoy was deployed at the RDL. Although observer logs indicate that 99% of the disposal events were at the proper coordinates, it is possible that some barges did not dump at the exact location.

Preliminary observations utilizing remotely operated video cameras revealed that fresh rock disposed in 1992 and 1993 is not yet colonized by hard bottom epifauna, but is providing habitat for lobster, redfish, cunner, cod, ocean pout, longhorn sculpin and other fish (Peter Auster, National Undersea Research Center, personal communication). Lobster pot buoys have been observed near these rock areas, so the rocks may be potential lobster habitat. Clearly, monitoring the colonization of these sites is important because of disposal of rocks from future projects.

5. Industrial waste site

Most of the waste drums are currently located in the northwest quadrant of the IWS (in an area around the coordinates 42°-26.4'N, 70°-35.4'W), or dispersed around the northern perimeter up to 0.5 nm outside the IWS (Wiley et al., 1992). Few drums have been observed away from the IWS or at the old Boston Lightship Disposal Site (US EPA, 1992). In 1992, EPA, NOAA, the Food and Drug Administration (FDA), and the Massachusetts Department of Public Health (MADPH) collaborated on a survey to determine whether hazardous and low level radioactive waste had leaked from the containers and accumulated in the IWS sediments, infauna and resident fish (NOAA, 1996). Underwater cameras confirmed earlier studies that most of the wastes appear to be encased in 55 gallon drums, indicative of toxic or hazardous wastes, not concrete "coffins", which was the most common method for disposal of low level radioactive waste. Radionuclides were not found in the sediments above background levels. Contaminants in sediments and tissue were similar to reference areas, except for some industrially related inorganic compounds -- antimony, beryllium, cadmium, cobalt and cyanide. In the majority of samples, levels of contaminants in fish (American plaice) and shellfish (quahog and lobster) tissue were similar to background, or reference concentrations **(Table 7)**. However, two composites of lobster tomalley collected at or near the site exhibited elevated PCB levels.

IV. SITE MONITORING PROGRAM

A. Conceptual model of impacts of disposal at the MBDS

Based on monitoring to date, impacts of dredged material disposal at MBDS are primarily restricted to the disposal mound itself where an altered, primarily Stage I benthic community occurs, and apparent RPD depths are shallow. The continuous dumping of dredged material at the "MDA" buoy appears to have maintained a disturbed habitat, which is constantly recolonized by opportunistic benthic epi- and infauna. It is expected that proper disposal at a defined mound will result in these conditions. Although the level of sediment contamination is slightly above background, or reference station levels, benthic infauna are not affected. Beyond the current disposal mound, no impacts have been noted. However, historical use of the "A" buoy area and the IWS has resulted in 1) slightly elevated toxicant levels and bioaccumulation in sediments west of the "A" buoy and in the IWS, and 2) elevated PAH and PCB levels in lobster tomalley collected from the IWS and MBDS area. Tissue burdens in edible fish are low and, based on present knowledge, do not pose a human health risk. There is evidence that a healthy benthic fauna is recolonizing the "A" mound. Levels of radionuclides in sediments and biota are not above background.

Although the ocean dumping criteria prevent unconfined disposal of unacceptable sediments, the disposal site is potentially the locus for the accumulation of contaminants in a relatively confined area, i.e. at the buoy location. Because of the recolonization of disposal mounds at the site and the constant disposal of dredged material, biota may accumulate contaminants. This is the major monitoring concern at the MBDS. Benthic organisms, from polychaetes to groundfish will be exposed to toxicants at and within 400 to 500 meters of the mound from the surge of sediments resuspended and settling during a disposal event. Direct bioaccumulation of particle-attached toxicants into bivalve molluscs, such as the filter-feeding ocean quahog and the deposit-feeding Yoldia is possible. The most likely food chain effect is accumulation (and possible biomagnification) of contaminants from sediments to benthic epi- and infauna (e.g. polychaetes, pandalid shrimp) to groundfish (e.g. American plaice). Another species at risk is the American lobster, an omnivorous feeder of bottom-dwelling fauna. A less likely, but important from a resource protection perspective, scenario is the transfer of contaminants from suspended particles to sandlance and then to humpback or sei whales.

B. The Ocean Dumping Act regulations and the DAMOS Tiered Monitoring Approach

In conducting a monitoring program, the Ocean Dumping regulations at 40 CFR §228.10 suggest the following types of effects, among others, to consider:

1) Movement of materials into estuaries or marine sanctuaries (e.g., the Gerry Studds Stellwagen Bank National Marine Sanctuary), or onto oceanfront beaches, or shorelines;

2) Movement of materials toward productive fishery or shellfishery areas;

3) Absence from the disposal site of pollution-sensitive biota characteristic of the general area;

4) Progressive, non-seasonal, changes in water quality or sediment composition at the disposal site, when these changes are attributable to materials disposed of at the site;

5) Progressive, non-seasonal, changes in composition or numbers of pelagic, demersal, or benthic biota at or near the disposal site when these changes can be attributed to the effects of materials disposed at the site; and

6) Accumulation of material constituents (including without limitation, human pathogens) in marine biota at or near the site (i.e., bioaccumulation).

Many of these issues have been incorporated into the DAMOS Integrated Tiered Monitoring Approach for monitoring capped and uncapped dredged material disposal mounds in New England (Germano, Rhoads and Lunz, 1993). The recommended sequence of monitoring activities for uncapped mounds is presented in flowchart form in **Figure 9**. Conceptually, this tiered approach is prospective, in that it attempts to identify early warning indicators of adverse effects, and is based on hypothesis testing using sampling technologies with rapid data return. Monitoring is used to test whether:

1) dredged material disposal is complying with the regulations;

2) assumptions in our model of impacts are correct; and

3) trends exist in impacts that would suggest a change in dredged material management.

In general, recolonization status and sediment quality (as monitored by sediment profile cameras) are used as measures of the overall physical, chemical and biological status of the disposal mound. The assumption is that benthic recolonization indicates compliance with dredged material disposal regulations. If the sediment profile camera documents slower than predicted recolonization rates, a more intensive evaluation and sampling effort would be triggered. Reliance on the sediment camera as a screening tool is advocated primarily due to cost-effectiveness; large numbers of sampling locations can be evaluated with a quicker data-turnaround and at lower cost than other sampling techniques (e.g., sediment chemistry analyses, conventional benthic community analyses, diver surveys).

The sediment profile camera can gauge sediment grain-size, relative sediment water content, sediment surface boundary roughness, seafloor disturbance, apparent RPD depth, sediment methane, and infaunal successional stage (Germano, Rhoads and Lunz, 1994). The DAMOS program uses many of these parameters to calculate an Organism-Sediment Index (OSI), a measure of the overall quality of the benthic environment, for each station. This sediment camera-based approach, however, cannot determine whether bioaccumulation of tissue contaminants is occurring, and requires some amount of "ground-truthing" (e.g., traditional benthic community surveys) to verify reliance on the photo-interpreted results (see below).

The DAMOS tiered approach recommends considerably more monitoring effort for capped mounds than for uncapped mounds in order to ensure the physical and chemical isolation of the problematic underlying sediments. The tiered approach for monitoring capped mounds is briefly discussed in section IV.D.

The DAMOS approach also recommends monitoring frequencies for both confined (i.e., capped) and unconfined disposal mounds. For uncapped mounds, an annual survey, with a gradually declining monitoring frequency is suggested if benthic recolonization rates are acceptable. It should be noted that this tiered monitoring approach is not intended to be an overly rigid monitoring scheme, but allows for flexibility as additional issues or objectives become identified.

C. Proposed monitoring program

The evaluation of impacts from disposal at the site will be accomplished through a comparison of the conditions at the disposal mound to conditions at historical and unimpacted nearby reference stations. Effects suggested in 40 CFR §228.10 will be considered. The tiered DAMOS approach will be followed, with some modifications. Timing of monitoring surveys and other activities will be governed by funding resources, the frequency of disposal at the site, and the results of previous monitoring surveys.

1. Objectives

The five objectives of the monitoring plan proposed here are to determine whether:

<u>1) dredged material remains within a confined mound</u>

This will be accomplished by annual or biennial monitoring of the site with precision bathymetry, side scan sonar or sediment acoustic characterization, and sediment profile imaging.

2a) benthic recolonization of the mound occurs
2b) the benthic community beyond the mound is not altered

This will be accomplished by annual or biennial sediment profile imaging, and biennial or triennial benthic community analyses to ground-truth the sediment profile camera results. (The first benthic community analysis should be conducted immediately.) These surveys should be performed within several months after specific disposal events. A benthic community analysis would also determine the spatial influence of disposal activities on Stage III fauna, or determine whether pollution-sensitive taxa are absent beyond the mound. If the results of these tests indicate that recolonization is not occurring, or that Stage III fauna are absent away from the mound, then sediment toxicity tests should be conducted immediately. (When available, *in situ* toxicity testing will be performed.)

3a) contaminants are not accumulating in sediments at the disposal site and the reference areas

This will be accomplished by annual or biennial (depending on amount of sediments disposed) sampling of sediments for chemical analysis, and screening for bioaccumulation (see 3b). If levels of many (e.g. >5) contaminants are significantly greater than recently disposed sediments than bioaccumulation tests should be performed (see 3b).

To test hypotheses 1, 2a, 2b and 3a, samples will be collected routinely from a) the "MDA" disposal mound, b) transects radially away from the disposal mound up to 1000 meters from the center, c) station 18-17, outside the MBDS, but suspected to be impacted by dredged material, and d) the three reference areas -- "FG-23", "SE" and "Ref-A". An analysis of variance statistical approach may be utilized to compare stations or areas to reference conditions or disposed sediment.

3b) contaminants are not accumulating in biological resources beyond the mound

Based on the sediment chemistry monitoring, the theoretical bioaccumulation potential (TBP) will be calculated as described in Section 10.2 of EPA/Corps (1991). If the TBP model results in concentrations above acceptable levels (see below), biennial or triennial sampling of tissue from four resident species --

ocean quahog, lobster, American plaice, (and humpback whales[2]) -- and important forage species, such as Nephtys (or other polychaetes) and sandlance, in and around the MBDS should be explored. To relate contaminant levels to biological effects, a baseline study of histopathology of American plaice will also be considered.

4) the benthic community at the "A" mound is recovering from historical dredged material disposal

This should be accomplished by biennial or triennial sediment profile imaging, bottom grabs with benthic community analysis, and toxicity testing at the "A" mound, and radially away from the center, including station "12-3". Results of these surveys will assist in verifying assumptions of the conceptual model of benthic impacts of dredged material disposal.

5) the Rock Disposal Location, and nearby rock debris, are colonized by a healthy hard rock epifaunal and fish community

This should be accomplished by biennial video or trawl sampling of the community at the RDL and appropriate reference areas to be determined in cooperation with the Gerry Studds Stellwagen Bank National Marine Sanctuary and the National Undersea Research Center (NURC).

D. Issues for monitoring methods

The DAMOS program methods are generally accepted techniques with an adequate amount of testing to verify assumptions. These methodologies include sediment profile imaging, precision bathymetry, and side scan sonar. New technologies to observe the ocean bottom remotely, such as sediment acoustic characterization and laser line scanning, are also being tested by NED. Other methodologies are discussed below.

1. Traditional Benthic Assessments

The DAMOS tiered monitoring approach does not recommend traditional benthic community assessment methods (i.e., collecting and counting numbers of species and individuals), relying instead on sediment profile imaging technology extensively as a surrogate for benthic recolonization. This monitoring plan recommends that traditional benthic assessments be performed immediately, and once every two to three years

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[2]This will require a special permit under the Endangered Species Act from the National Marine Fisheries Service.

thereafter. There does not appear to be adequate sediment profile camera groundtruthing in sediments north of Long Island Sound. This assessment would confirm the assumptions employed by the sediment profile imaging system, and support the regulatory requirement to consider the "absence from the disposal site of pollution-sensitive biota characteristic of the general area" as a possible effect of dredged material disposal.

2. Sediment toxicity testing

To date, the only sediment toxicity testing performed on sediments from the MBDS has been near the "A" buoy (see above). The DAMOS tiered monitoring approach calls for sediment toxicity testing (Tier 3) only in the case of abnormal benthic recolonization rates, as observed via sediment camera. Results in 1994 at the "12-3" station indicate no sediment toxicity. However, this test, requires manipulation of sediments (i.e. collection, homogenization, and screening) which may alter the bioavailability of some sediment contaminants compared to *in situ* conditions. EPA will collaborate with NED in promoting research and development of *in situ*, or other appropriate tests, and study the effects of manipulation on toxicity (and bioaccumulation).

3. Bioaccumulation Testing

Bioaccumulation of contaminants into resident species has been identified as the most important monitoring concern at MBDS, because of its importance in assessing potential risks to human health via the marine food chain. However, bioaccumulation is recommended by the DAMOS tiered monitoring approach as a measure of upward contaminant migration at capped sites only. The analytical costs for bioaccumulation testing are expensive, and the collection of sufficient tissue for statistical testing is difficult. Interpretation of bioaccumulation results for post-disposal monitoring is problematic because existing scientific knowledge is inadequate in determining whether a given tissue concentration is harmful. As in toxicity testing, laboratory tests are difficult to interpret since manipulation of the sediments may change the bioavailability of some of the sediment contaminants.

The use of the theoretical bioaccumulation potential model, as described in Section 10.2 of EPA/Corps (1991), can provide useful screening data to assess the accumulation potential of non-polar organics such as polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) and pesticides. PCBs and pesticides are particularly problematic as they may be biomagnified in the food web. Based on sediment chemistry, total organic carbon and lipid levels of the organism of concern, concentrations in tissues can be predicted and compared to reference values, FDA action/tolerance levels, state advisory levels or used in a risk assessment without incurring large costs. If the TBP exceeds acceptable values which would be determined at the time, further monitoring could be pursued. While existing scientific knowledge is generally lacking in determining whether a given tissue concentration is at a harmful level, EPA and the Corps have been making efforts to develop interpretive guidance for assessing bioaccumulation data at both the regional and national levels. When appropriate, risk assessment techniques will be used to determine the potential for adverse effects. Thus, tissue sampling or lab testing can be used to supplement sediment monitoring at a later tier.

The Corps and EPA have and will continue to strive to progressively resolve bioaccumulation issues and ways to best integrate bioaccumulation assessments in future monitoring.

4. Fisheries Habitat Studies

Studies should be conducted at the RDL to determine whether bottom habitat has been sufficiently altered by disposal of hard rocks onto a gravelly sand and cobble environment. The rocks provide habitat for hard bottom or rock-dependent fish species at the expense of soft bottom dependent species. The hypothesis is that the fish community is not significantly altered beyond the influence of the RDL. Trawls and video transects should be conducted at the RDL and in appropriate hard and soft bottom reference areas. The results may provide information for effects of disposal of hard rocks onto a gravelly sand and cobble, and soft bottom environments.

5. Capping Studies

Capping contaminated sediments at the MBDS is currently not allowed. The Record of Decision for the Designation of the MBDS states that "if capping pilot studies are proposed, they should utilize clean dredged material to ensure the protection of the marine environment in case of failure" (EPA Region 1, 1993). However, NED has proposed a demonstration project to test whether clean sediments from Cohasset Harbor can be capped effectively at MBDS. In 1997, NED and EPA, with NMFS and Stellwagen Bank Sanctuary personnel, will develop an appropriate monitoring plan to determine whether capping is effective. This will include monitoring the spatial extent and permanence of the cap using principles outlined above and in Germano et al., 1993. (EPA and the Corps have developed a draft capping guidance document, which may be released in the near future). Measurements of bottom currents may be performed to better characterize the response of capped sediments to storm conditions.

E. Quality Assurance

An important part of any monitoring program is a quality assurance (QA) regime to ensure that the monitoring data are reliable. Quality assurance has been described as consisting of two elements: quality control and quality assessment. Quality *control* activities are those taken to ensure that the data collected are of adequate quality given the study objectives and the specific hypothesis to be tested, and include standardized sample collection and processing protocols and technician training (National Research Council, 1990). Quality *assessment* activities are implemented to quantify the effectiveness of the quality control procedures, and include repetitive measurements, interchange of technicians and equipment, use of independent methods to verify findings, exchange of samples among laboratories and use of standard reference materials, among others (NRC, 1990).

Site monitoring to date has included many of these QA components, especially the use of replicate sampling for sediment chemistry, sediment camera, and benthic community analyses. QA issues for the MBDS which the Corps and EPA will discuss and resolve include:

1) DAMOS sediment chemistry analyses have been performed almost exclusively by the NED laboratory, mainly due to cost-effectiveness. While this promotes analytical standardization and precision, assessments of analytical accuracy and inter-laboratory variability could be made by splitting samples with other laboratories for comparison;

2) the use of standard reference materials (SRMs) for sediments and tissues as discussed in the Green Book would provide an additional measure of analytical accuracy;

3) verification of sediment camera results by ground-truthing with traditional benthic community assessments as discussed above; and

4) the use of positive control sediments ($CdCl_2$) as well as negative (clean) control sediments for sediment toxicity testing.

F. Data and information management

EPA and NED will set up a computerized database to keep track of the results of the reference area sediment chemistry, toxicity and bioaccumulation tests required for Tier 3 permit review. In addition, EPA and NED will produce and distribute a site map which will include detailed bathymetry, locations of disposal mounds and priority sampling stations, reference areas, selected geologic and anthropogenic features, and the Stellwagen Bank Sanctuary boundary. The DAMOS program will continue to publish results of disposal site monitoring, in response to monitoring objectives, in a series of NED reports. Other reports will be published periodically on special management or monitoring issues.

G. Independent Peer Review

An important part of the DAMOS Program is its reliance on a Technical Advisory Panel that meets periodically to review program results and recommend program changes. This panel is made up of five internationally recognized experts and meets at least every three years, although at times has met more frequently when NED has been developing major program elements. This approach is consistent with good marine monitoring program management (NRC, 1990). EPA plans to work with NED to support this continuing effort.

Briefly, the mission of the panel is to perform an independent assessment of the DAMOS and EPA site monitoring activities, and to provide recommendations for restructuring or modifying the site monitoring process as necessary. Topics for review include recent monitoring results, and new (or different) monitoring techniques, among others.

This peer review process is also an opportunity to discuss overall site management strategies. For example, should consideration be given to the concept of disposing dredged material on existing, successfully recolonized mounds (depth permitting) as opposed to the creation of new mounds on the ambient seafloor? Should some limited areas be left uncapped for additional research needs? Perhaps recommendations could be made for progress on the "comparative risk assessment" issue. That is, what are the comparative risks of leaving problematic sediments in near shore areas used for spawning and nurseries, as opposed to dredging and disposing them in off shore, open water areas?

H. Public Involvement

The New England Division has and continues to inform and involve the public. The DAMOS Program holds periodic symposia to report results and seek comment on the program. These symposia have typically been held every three years. DAMOS monitoring results are published in an ongoing series of technical reports which are mailed to interested people and organizations and also distributed at various public meetings. NED also has prepared and distributed several Information Bulletins and brochures. On a regular basis NED fulfills requests for speakers on this topic. To better meet this need, a series of presentations on different aspects of the dredging and disposal process is being prepared. These presentations are being structured to be thought provoking and to encourage discussion. Once complete, these presentations will be made available to interested groups or organizations throughout New England. Libraries which receive the DAMOS technical reports are listed in Appendix A. In addition, site related reports can be reviewed at both the NED Technical Library and the EPA regional library:

U.S. EPA Region 1 (New England)
Library
One Congress St., 11th Floor
Boston, MA
Hours: Monday-Friday 8:00-5:00
Telephone: (617) 565-3300

U.S. ACE
NED Technical Library
424 Trapelo Road
Waltham, MA 02254-9149
Hours: Mon-Fri 7:30-4:00
Telephone: (617) 647-8118

Any party interested in being added to the DAMOS mailing list should mail the appropriate information to NED at:

U.S. Army Corps of Engineers, New England Division
Regulatory Division
Marine Analysis Section
424 Trapelo Road
Waltham, MA 02254-9149

V. SITE MANAGEMENT STRATEGY AND INTER-AGENCY COORDINATION

A. Routine Site-Specific Management Practices for Protection of the Marine Environment

To ensure a disposal program which minimizes impacts to the marine environment, the following management practices will continue to be implemented at the MBDS as a matter of routine policy. First and foremost, as discussed in section II.C (Estimated quantity and quality of dredged material to be disposed), all proposed dredging projects will be reviewed for suitability for ocean disposal by both the Corps and EPA.

An interagency dredged material management review group composed of representatives from EPA, NED, NMFS and USFWS (U.S. Fish and Wildlife Service) and occasionally with state representatives meets approximately every two months to discuss management and monitoring of New England dredged material disposal sites.

In order to assess compliance with applicable permit conditions and to track overall site usage, permittees will continue to be required to provide written documentation of disposal activities to the Corps during disposal operations and after dredging is complete. Disposal permits will continue to include standardized requirements for this reporting to include the source of the dredged material, the amount of the material disposed, the rate of disposal, the date, time and LORAN-C coordinates (or differential GPS, if available) of disposal as well as the due-date for the documentation itself.

The Corps will provide EPA with summary information on each project at two stages of the dredging and disposal process. A Summary Information Sheet will be provided when dredging operations begin, and a Summary Report will be submitted when dredging operations have been completed.

Point dumping will continue to be practiced using a taut-wire buoy to ensure that ultimate disposal locations are known and that post-disposal monitoring is effective. On-board inspectors will be used by the Corps for all disposal activities at the MBDS to ensure compliance with this policy. These inspectors are trained and certified by the Corps specifically for the dredged material disposal program. Any instances of non-compliance observed by the inspectors must be reported to the Corps within 24 hours and in writing to both the Corps and EPA within five working days of the observed violation. Both agencies will cooperate to ensure effective enforcement of all disposal requirements. §105 of the MPRSA gives authority to EPA to enforce permit conditions. Egregious violations of permit conditions may be referred by the Corps or EPA to the Department of Justice for criminal prosecution. Disposal activities will not generally be performed during poor sea conditions. Inspectors have been issued specific guidance on disposal under these conditions ("Guidance for Inspectors on Open-Water Disposal of Dredged Material, NED, January 1996).

Survey cruises will be conducted at least annually, provided funding is available. EPA and NED will coordinate their monitoring efforts to ensure at least one monitoring survey per year. The monitoring objective for each survey will be based on prior monitoring results and recommendations of the interagency dredged material management review group, in consultation with MA Massachusetts Department of Environmental Protection (DEP), Coastal Zone Management (CZM) and Stellwagen Bank Sanctuary personnel.

B. Management, Distribution and Review of Monitoring Information

In addition to a strong enforcement effort, the overall credibility of the open water dredged material disposal program depends on a robust monitoring and data evaluation program. Timely receipt and review of the monitoring data and information is critical in order to either validate hypotheses of acceptable impact or to trigger remedial action to mitigate unreasonable impact. It is therefore an overall goal of this plan to shorten the lag time between generation of the survey data and receipt and review of it by the applicable public agencies.

To this end, and consistent with the DAMOS program's tiered monitoring approach, EPA and NED will meet annually with Massachusetts DEP, CZM, NMFS and Stellwagen Bank Sanctuary personnel to review and discuss recent monitoring results and recommend future monitoring activities. Because of limited funding, monitoring activities must be ranked in order of priority. EPA will take the lead role in organizing these meetings, and NED and EPA will ensure availability of all pertinent survey data in advance of the meetings. These meetings are expected to occur within six months of each survey cruise, and about six months in advance of an upcoming survey (assuming annual cruises). Meetings may be scheduled more or less frequently, if warranted. Follow-up recommendations for more intensive sampling or corrective action as a result of these meetings should generally be consistent with the DAMOS tiered monitoring approach and the site management and monitoring plan described in this document.

The interagency dredged material management review group will also discuss important issues specific, or unique to MBDS. In 1997, the following issues will be discussed:

Capping: A monitoring plan for a demonstration project on deep water capping using clean sediments from Cohasset Harbor is being developed.

Seasonal restrictions: At this time, there are no seasonal restrictions on dredged material disposal. A workgroup will be convened to discuss whether restrictions should be in place to avoid and protect marine mammals or other sensitive species.

C. Corrective Site Management Practices in the Event of Unacceptable Impacts

Effective implementation of the dredged material permit program as discussed above should prevent adverse impacts to the site environment. However, it is important to have contingency plans in place. The DAMOS tiered monitoring program includes early warning indicators of potential environmental impacts so that corrective actions can be implemented in a timely fashion.

If site monitoring demonstrates that disposal activities are causing unacceptable impacts to the marine environment, EPA and NED, in consultation with NMFS, USFWS, MA DEP and MA CZM will place appropriate limitations on site usage to reduce the impacts to acceptable levels. These limitations can range from withdrawal of the site's designation as a disposal area to various limitations on the amounts and types of dredged material permitted to be disposed and on the specific method, location or schedule of their disposal. Other potential corrective measures include, but are not limited to:

1) follow the tiered monitoring protocol, initiate more intensive benthic sampling (sediment chemistry, sediment toxicity, body burdens, etc.) to verify the impact, refine the spatial extent of the problem and attempt to find a causative agent(s) in order to prevent future occurrences;

2) implementation of more protective judgements on whether sediments proposed for dredging are suitable for open water disposal (i.e., to allow less material to be disposed);

3) stricter definition and enforcement of disposal permit conditions;

4) specific changes in the method, location or time of disposal in response to any questionable impacts observed;

5) placement of suitable material on top of an area or mound of concern in appropriate thickness and spatial extent to physically and chemically isolate the problem sediments;

6) excavation and removal of any highly toxic sediments from the disposal site (an unlikely, worst-case scenario given that the permitting program should exclude such material from the site to begin with, and since excavation could make matters worse by releasing contaminants during the process); and

7) closure of the site as an approved dredged material disposal area (i.e., to forbid any additional disposal at the site).

D. Protection of Endangered Species

Table 6 lists the threatened and endangered species occurring in the general vicinity of the MBDS. Endangered species potentially impacted by the MBDS are best protected by ensuring compliance with the ocean dumping criteria. In preparing the Environmental Impact Statement/Designation of the MBDS, the EPA initiated a Section 7 consultation with the National Marine Fisheries Service. Based on a review of the Draft EIS, the NMFS concluded in a November 7, 1991 letter and Biological Opinion to EPA that "final designation of the MBDS will not jeopardize the continued existence of any endangered or threatened species under our jurisdiction. However, disposal activities associated with the MBDS may adversely affect some of the species. Therefore, NMFS has developed conservation recommendations to minimize adverse effects." Some of these recommendations have been incorporated into the Corps' training program for on-board inspectors, which includes information to increase the inspectors' awareness of and ability to identify threatened and endangered species expected to be found in the general site area. If any of these species are sighted during site activities the vessels will be controlled to avoid interference with the animals, and the sighting will be reported to the National Marine Fisheries Service as soon as possible.

VI. LONG TERM SITE USAGE, ANTICIPATED CLOSURE DATE AND THE NEED FOR POST-CLOSURE MANAGEMENT

The MBDS is expected to continue to receive dredged material from coastal Massachusetts Bay. The disposal buoy will generally stay in the area of the current "MDA" buoy, although it may be moved to cover, with fresh dredged material, areas within the MBDS where sediments have higher chemical concentrations due to historical disposal.

Dredged materials for disposal are expected to be generated primarily from maintenance dredging (i.e., dredging to return navigational areas to previously existing depths). However, advances in naval architecture may lead to deeper-draft ships and the need for deeper channels to accommodate them. This is the motivation for the proposed improvement dredging in Boston Harbor.

A specific closure date for the MBDS site has not been assigned as of the date of this management plan. Because of its depth, the capacity of the site is clearly greater than current or historical use. Assuming that continued use of the site does not result in unacceptable impacts, it is anticipated that the site will be available for disposal of dredged material well into the next millenium. Based on an average disposal volume of 340,000 cubic meters, it would take about 130 years to raise the average depth of the site five meters, from about 90 meters to 85 meters.

If the MBDS continues to be managed in such a way that promotes and documents benthic recolonization, and if the potential for bioaccumulation has been addressed to a point where it is not a significant concern, then the amount of monitoring or management required after the cessation of all disposal activities at the site is expected to be reduced. The specifics of the post-closure monitoring plan will be determined and agreed upon in advance of site closure by the interagency dredged material management review group.

VII. SCHEDULE FOR REVIEW AND REVISION OF THIS PLAN

Consistent with §102(c)(3)(F) of MPRSA, as amended, EPA and NED agree to review this site management plan every ten years, and to revise it as necessary. This revision process may be undertaken more frequently if warranted by results of monitoring, or technical advances in site assessment methods. Revisions may be made in the form of amendment(s) to this plan, or by the execution of entirely new plans to supersede this one. In either case, all revisions must be signed by both the Corps and EPA, and notification must be given to other governmental agencies (e.g., MA CZM, MA DEP, NOAA, NMFS, USFWS, Stellwagen Bank Sanctuary, etc.) involved in marine protection.

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IX. FIGURE LEGENDS

Figure 1. Major bathymetric features in Massachusetts Bay, including the ***approximate boundary*** of the Stellwagen Bank National Marine Sanctuary, Former Industrial Waste Site (IWS), Interim (former) MBDS and new MBDS.

Figure 2. Figure 1-2 from SAIC, 1996b.

Figure 3. Tiered protocol for evaluation of dredged material based on EPA/Corps Regional Protocol.

Figure 4. Figure 1-3 from SAIC, 1996b.

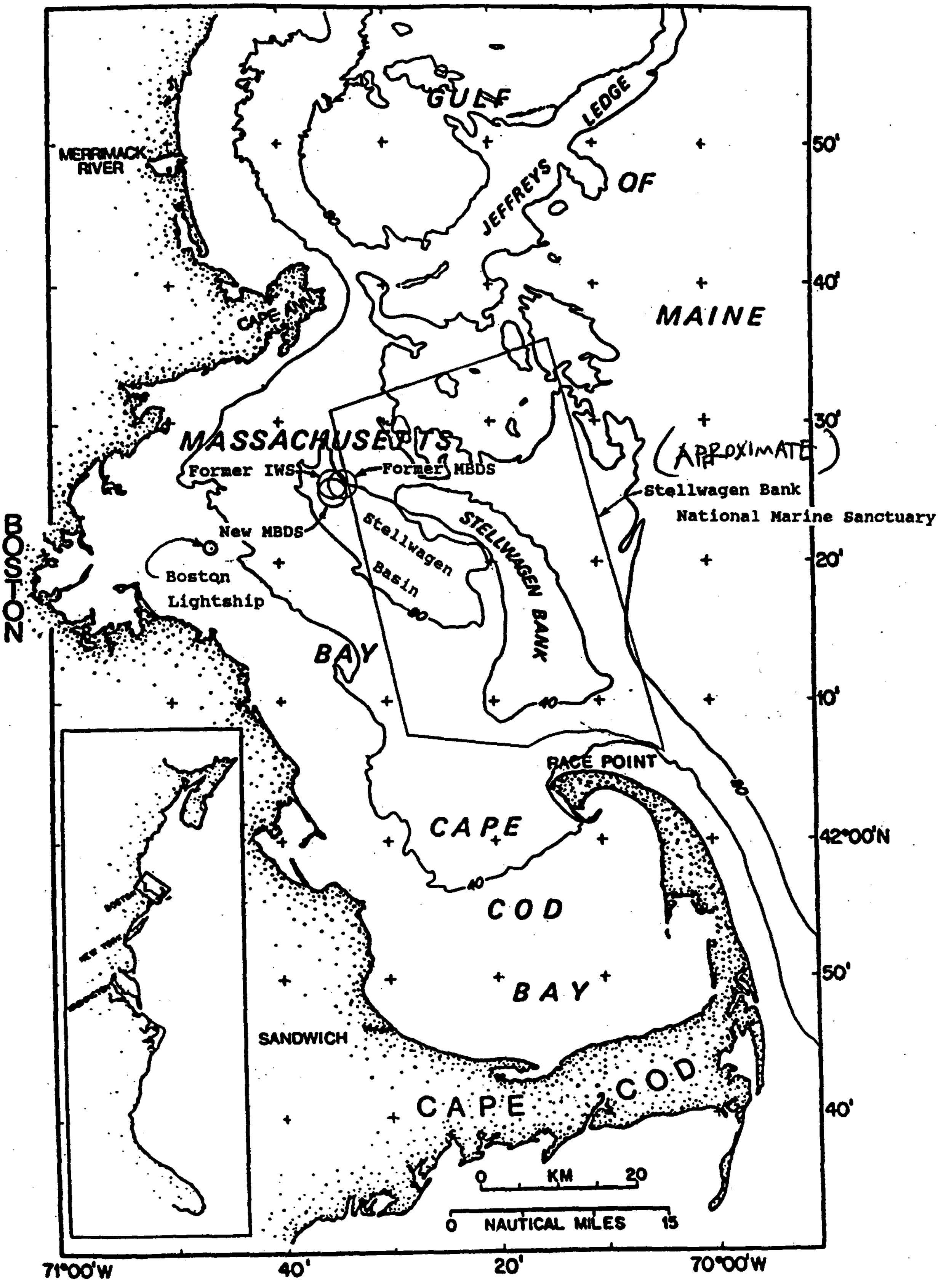
Figure 5. Figure 3-2 from SAIC, 1996b.

Figure 6. Figure 4-2 from SAIC, 1994.

Figure 7. HMW PAHs near Buoy "A". Sum of high molecular weight PAHs (ppb dry weight) collected from surface sediments at the MBDS. "Mean Ref 1989-1993" is the mean of reference areas (outside MBDS) collected from 1989 to 1993. "Mean MBDS 1989" is the mean of samples from within the interim MBDS only. "12-3" 1989, 1993 and 1994 is a sample from an area (near buoy "A" site) within the MBDS exhibiting elevated PAHs. "IWS" 1994 is from a sample within the IWS, west of buoy "A".

Figure 8. Toxicity of MBDS sediments. Number of amphipods (from two species) surviving after 10 day exposure to sediments from 1994 reference area, "IWS", "12-3" and control sediments.

Figure 9. Figure 2 from Germano et al., 1994. Tiered monitoring protocol for uncapped disposal mounds.



approximate

Figure 1 - Major bathymetric features in Massachusetts Bay, including the locations of the Stellwagen Bank National Marine Sanctuary and past and present disposal areas (depth countours in meters)

FIGURE 2

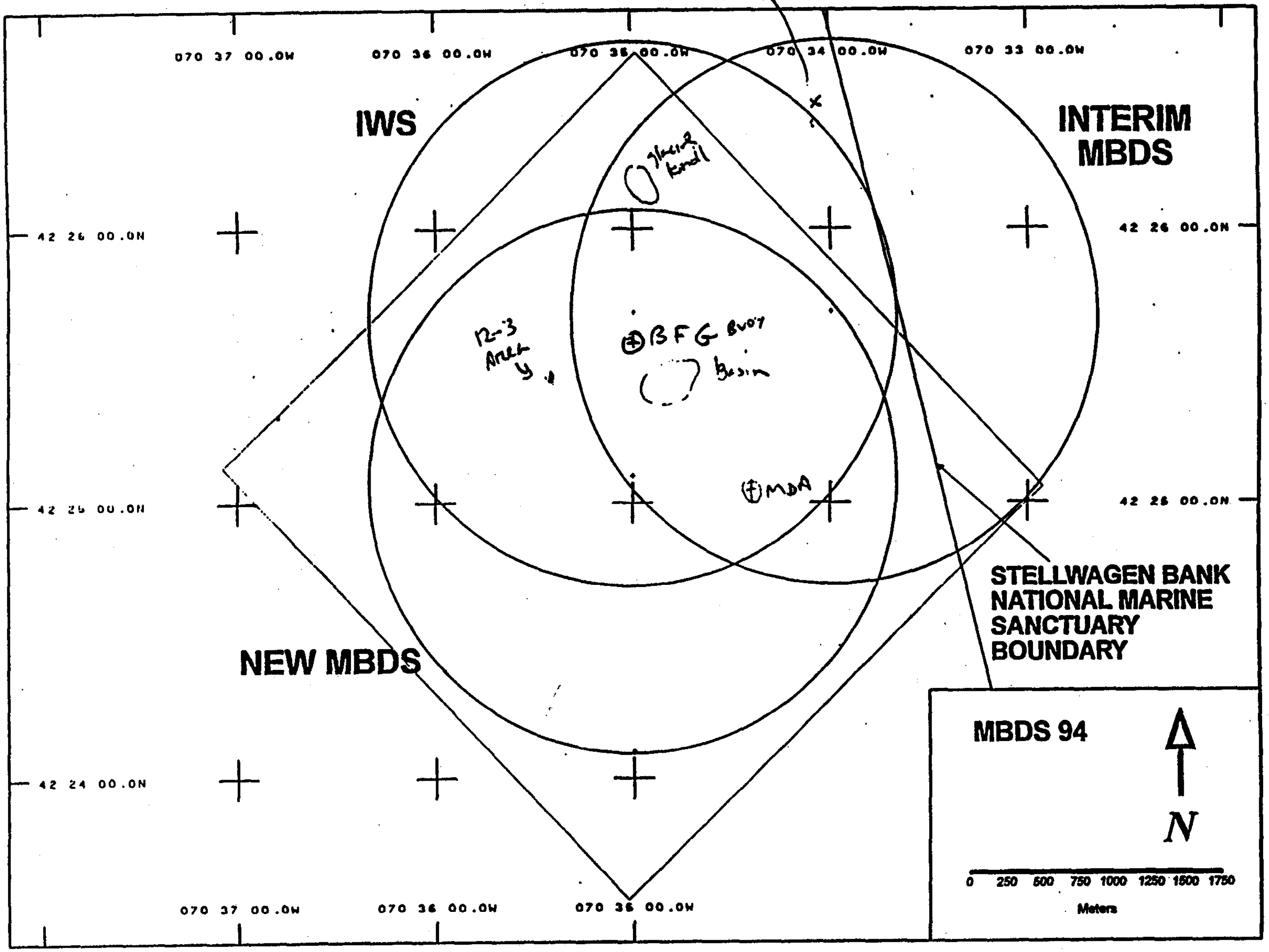


Figure 1-2. Location of MBDS in relation to the interim MBDS, the IWS, and the Stellwagen Bank National Marine Sanctuary boundary

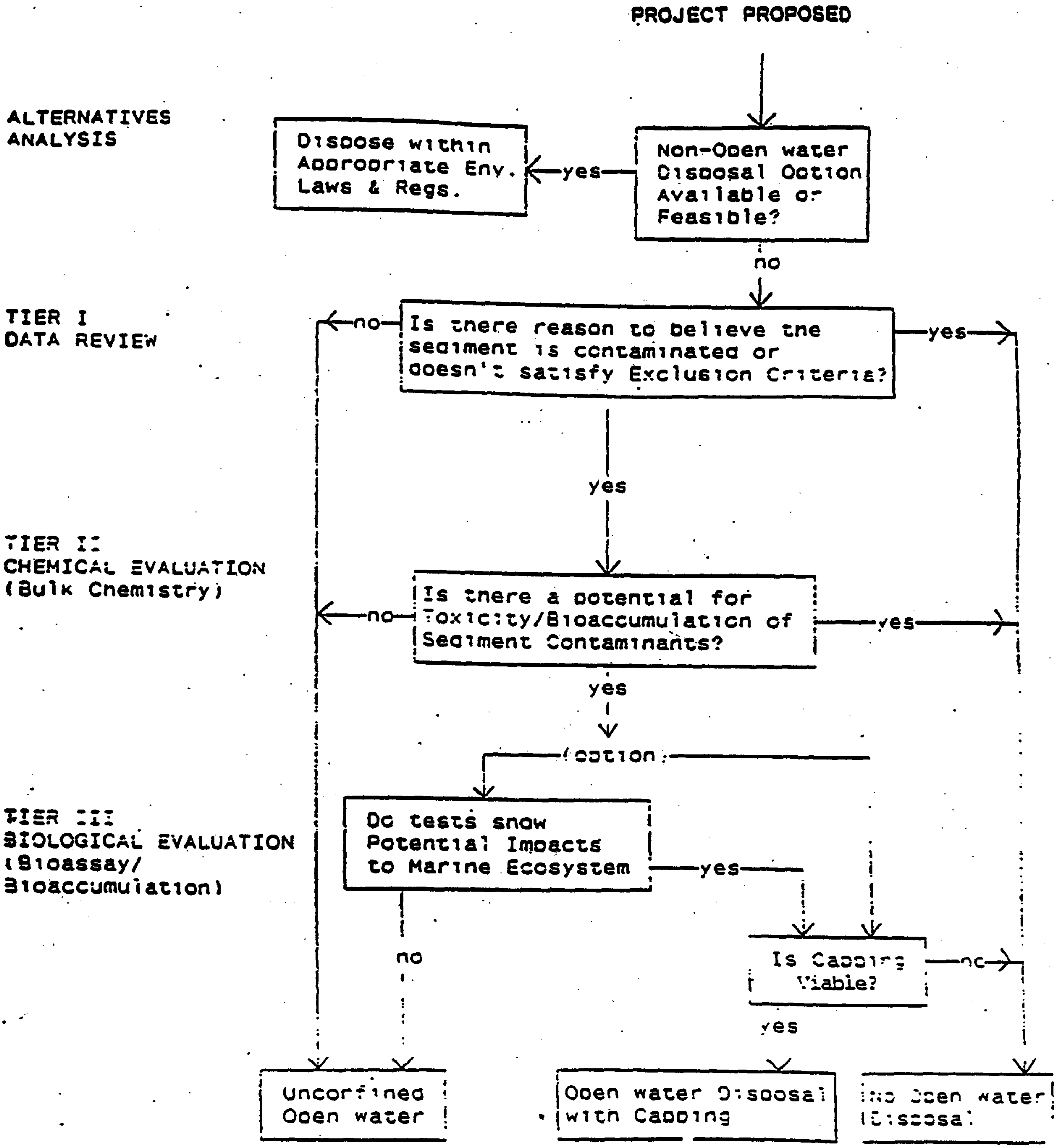


Figure 3 - Generic Flow Diagram for the Tiered Testing and Decision Protocol for the Open Water Disposal of Dredged Material

FIGURE 4

Monitoring Cruise at the Massachusetts Bay Disposal Site, August 1994

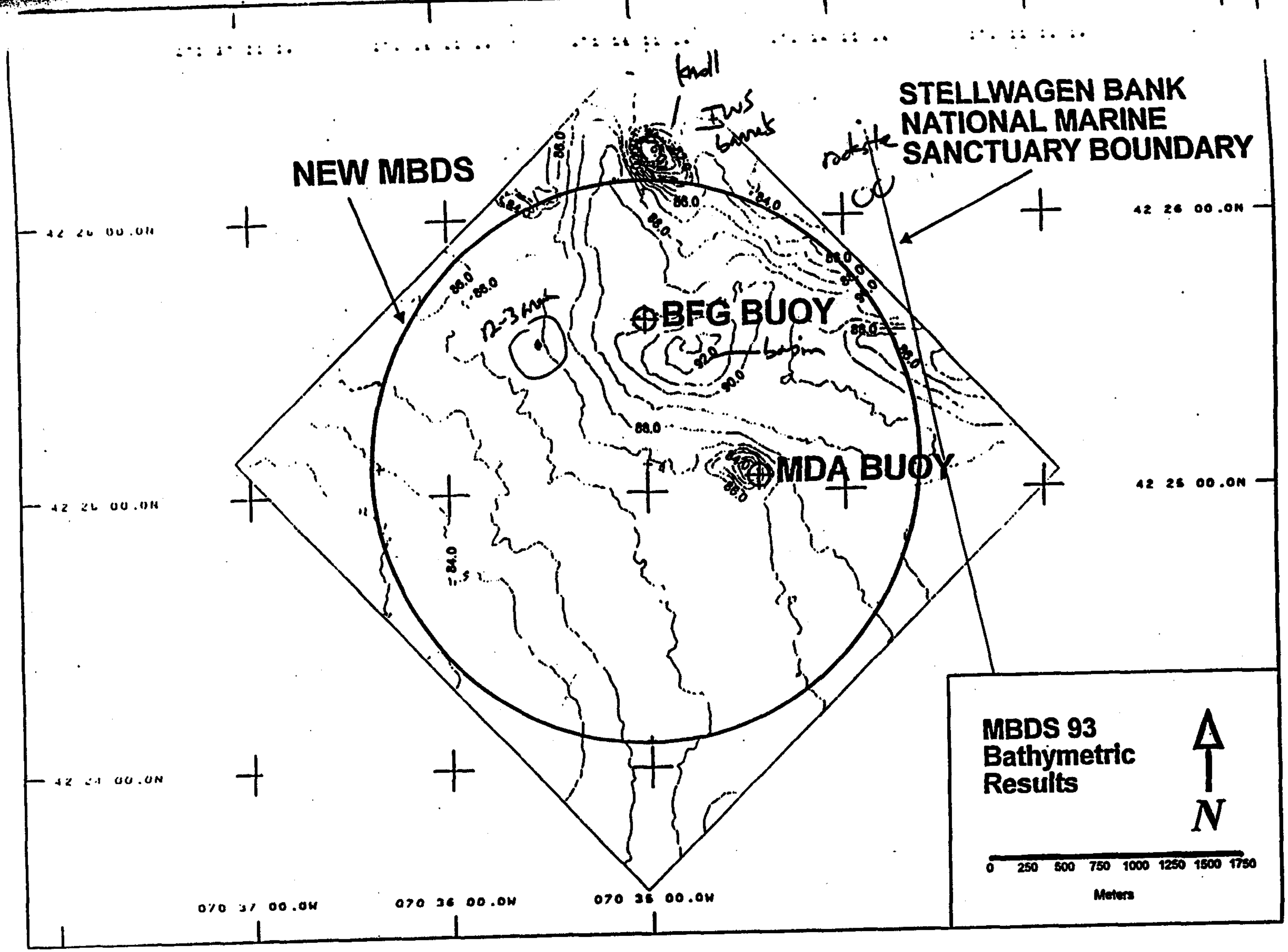


Figure 1-3. Bathymetric results from the 1993 MBDS baseline survey (depth in meters)

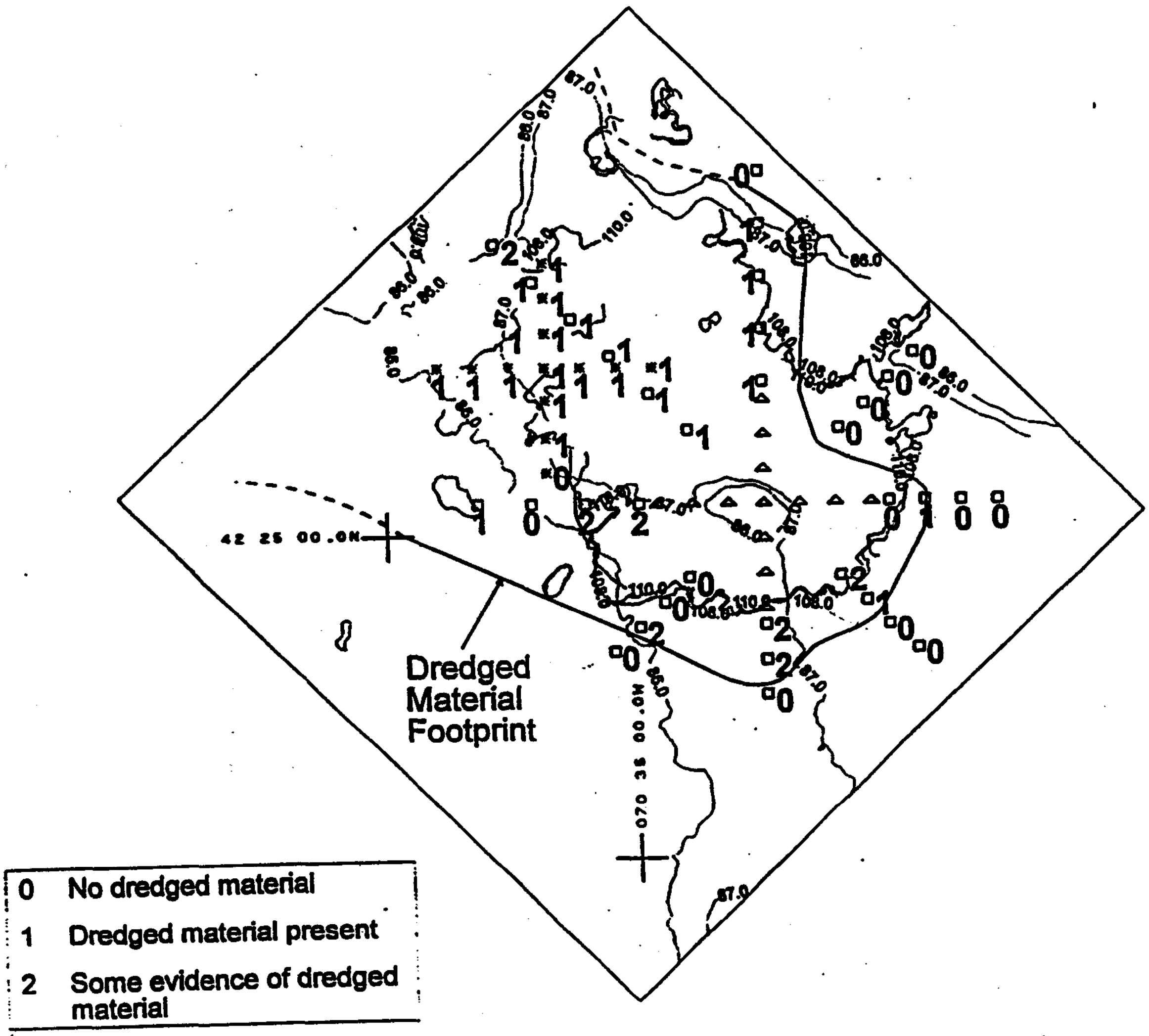


Figure 3-2. SACS REMOTS® stations showing the areal extent of historical dredged material, relative to the 110 dB SACS contour

FIGURE 5

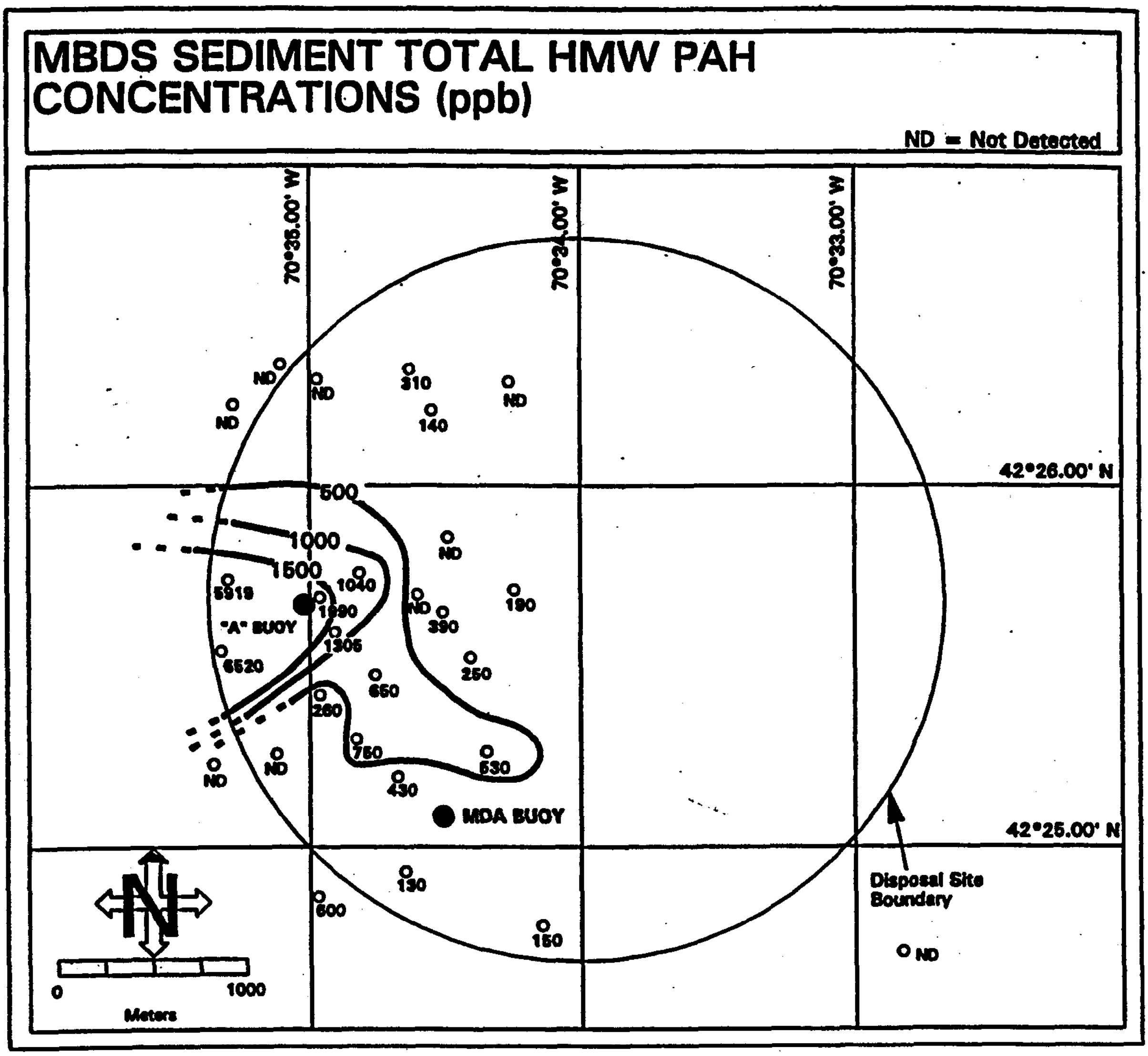


Figure 4-2. Contour map of total high molecular weight PAH concentrations (ppb)

FIGURE 6

Figure 7. HMW PAHs near buoy "A"

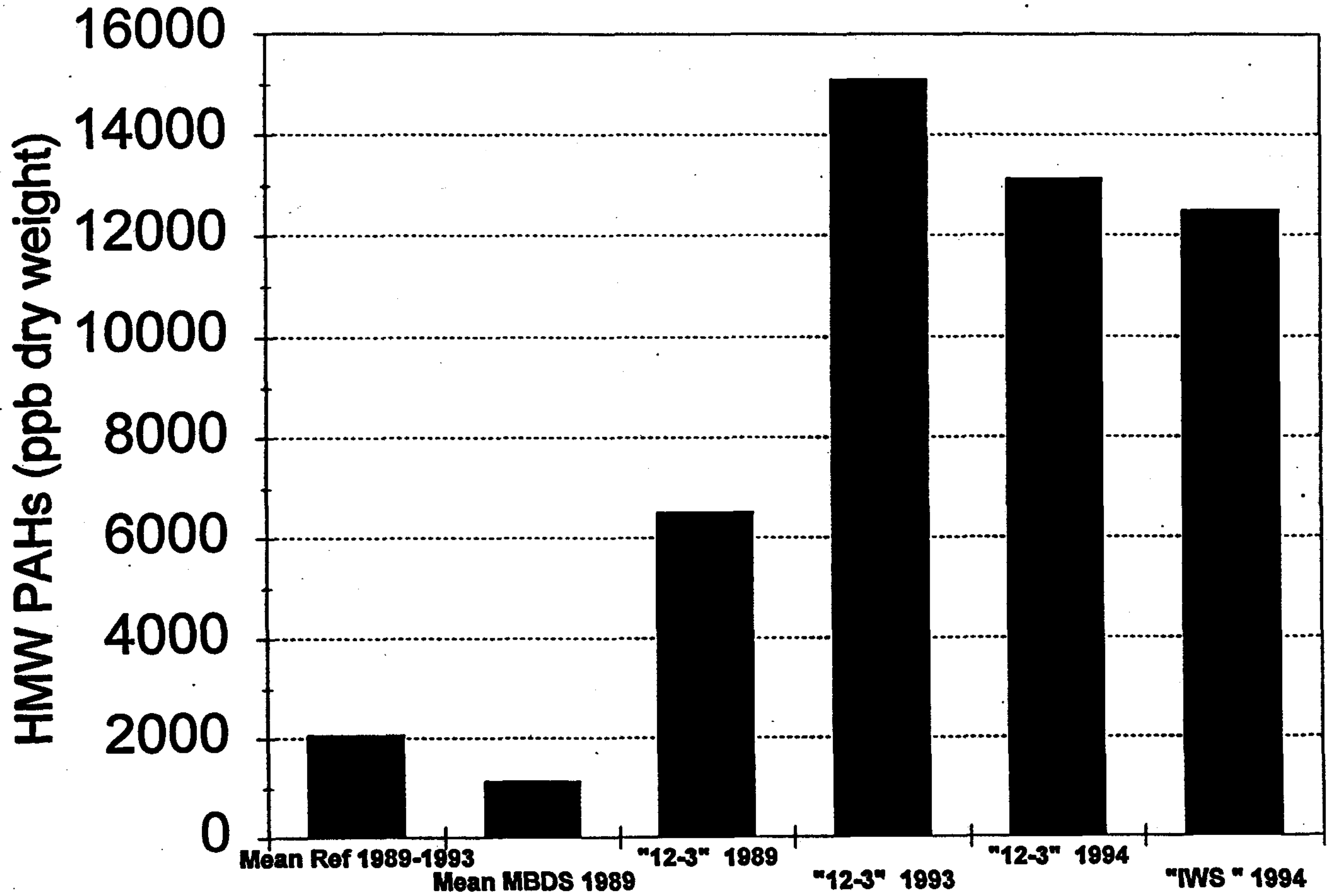


Figure 8. Toxicity of MBDS Sediments

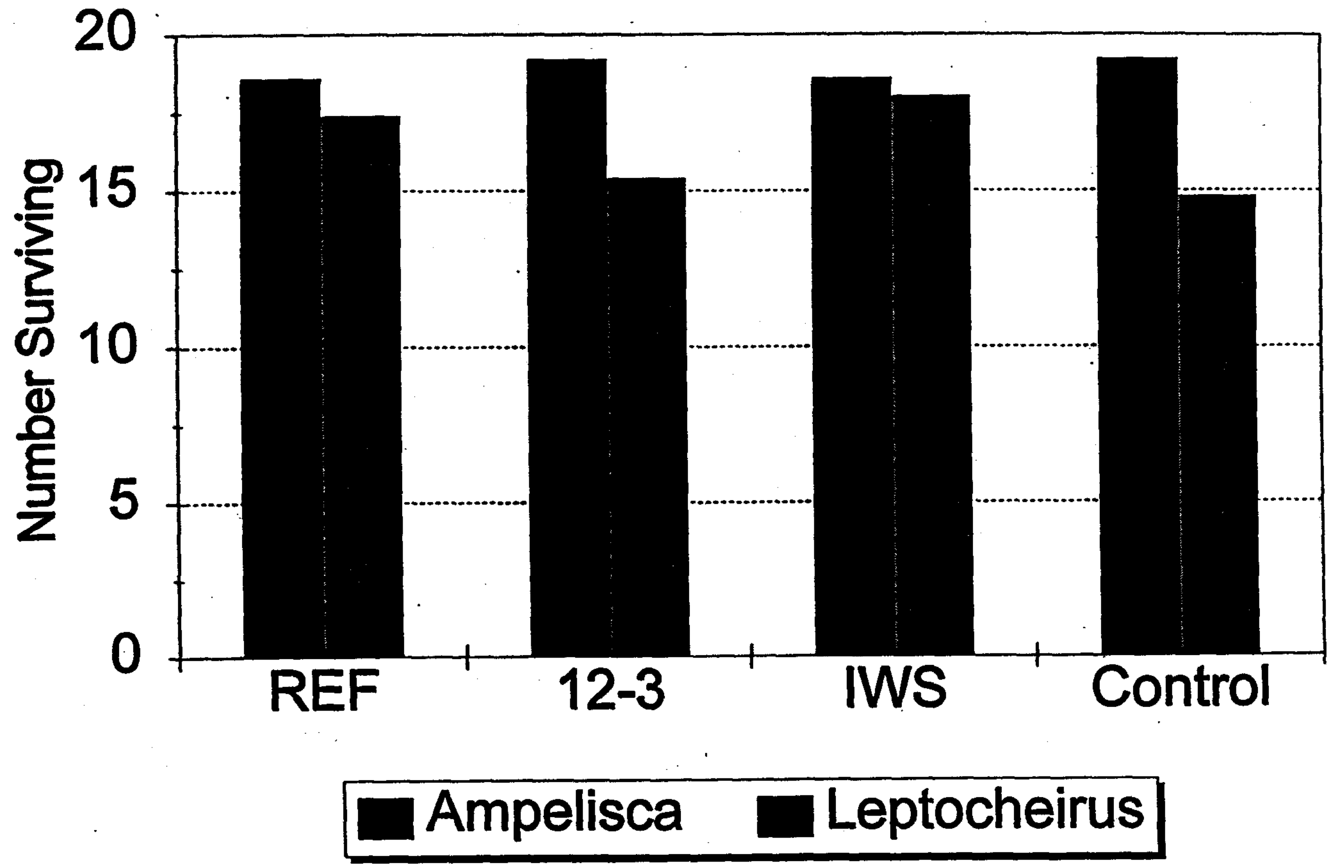


FIGURE 2. H_o1: ON AN UNCONFINED DISPOSAL MOUND, DREDGED MATERIAL DISPOSAL WILL RESULT IN BENTHIC POPULATION DENSITY GREATER THAN AMBIENT CONDITION

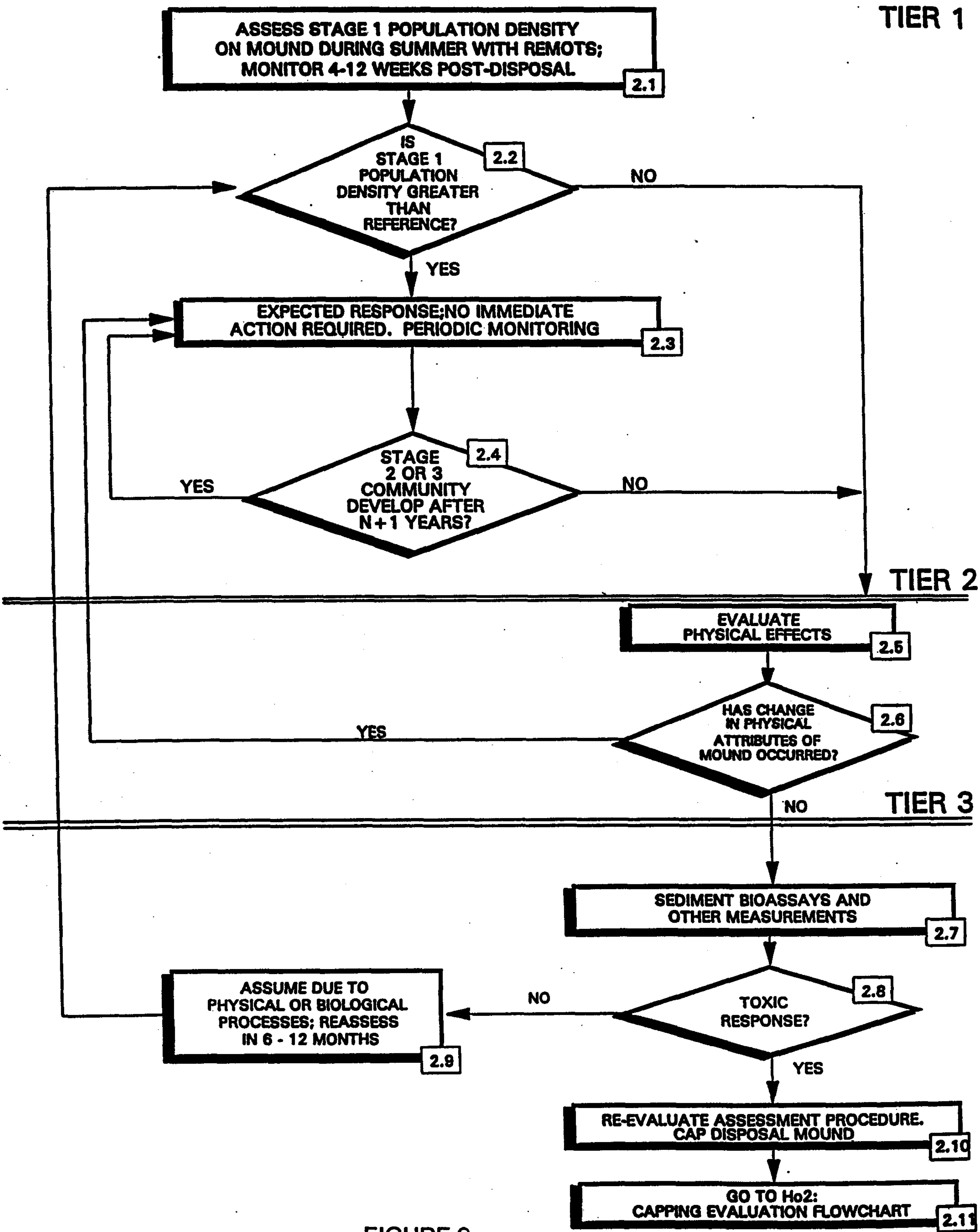


FIGURE 9

X. TABLES 2,7,8,9,10,11,12, AND 13

Table 2. Massachusetts Bay Disposal Site summary of past monitoring

Survey Date	Bathymetry	Sediment Profile Imaging	Sediment Chemistry: Metal	Sediment Chemistry: PAH	Sediment Chemistry: PCB	Sediment Chemistry: Pest	O&G	TOC	Water Column Chemistry: Metal	Water Column Chemistry: PAH	Water Column Chemistry: PCB	Water Column Chemistry: Pest	DO	CTD	Tissue Chemistry: Metal	Tissue Chemistry: PAH	Tissue Chemistry: PCB	Tissue Chemistry: Pest	Benthic Comm. Analyses	Major Findings
1974	Y	N	8	N	Y	N	Y	N	Y	N	N	N	Y	Y	N	N	N	N	Y	N. E. Aquarium benthic surveys included 5 stations in the IWS. Gilbert, 1975.
1975-76	N	N	N	N	N	N	N	?	Y	N	N	N	N	N	Y	N	N	N	Y	Additional surveys by the Aquarium. Stations around the perimeter of the IWS had the lowest mean number of species (44) and individuals (15,000/m2).
1978	Y	N	9	N	N	N	Y	?	N	N	N	N	N	N	D	N	N	N	Y	All metals relatively low. Cu and Pb decreased significantly from baseline in deployed mussels. 16 predominant species and 179 total benthic individuals in 3 samples, but no reference site to compare to. DAMOS Annual Report-1978, Supplement D.
1982-83	Y	N	6	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	Comparative study of hopper versus scow disposal: bathymetry accuracy unable to detect a mound assumed to be 25 cm thick. Poor positional control of scow barges, better point-dumping control with the hopper dredge (at least for this project). Elevated levels of As, Hg, Pb and Zn. D#41 (Draft only), summarized in in DAMOS summary report #46.
Jul 84	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Submersible & ROV surveys: visual indications of mound limits correlated with bathymetry. Notable near bottom (10m) turbidity layer present. No sign. difference in distribution of benthic fin-fish on or off the mound. Dense, patchy distribution of mysid and clusters of pandalid shrimp did not indicate avoidance of DM. D#46??
Oct 84 - Apr 86	Y	246	Y	Y	T	N	Y	Y	9	Y	Y	N	Y	Y	F	F	F	F	Y	Site evaluation studies; included REMOTS, BRAT survey, fish trawls, side scan sonar, current meters, etc. Cr, Cu, Pb & Zn (but not As) and PCBs significantly higher on site compared to ref. Tissue PCB conc. slightly elevated in organisms on dredged material compared to reference. Commercially important bottom-feeding fish inhabit the site; American plaice, cod and witch flounder were caught in greatest numbers. First REMOTS survey of interim MBDS. Dredged material depth detected 11 to 19 cm. Most DM observed to east and south of "A" buoy. Active recolonization hypothesized. Stage 1 on Stage 3 observed. Hubbard et al., 1988.
Feb 87	Y	73	8	N	T	1	Y	Y	N	N	N	N	N	N	N	N	N	N	N	Area surveyed was the active disposal area: two camera stations were azoic, but all others given a Stage 1 on Stage 3 status. Low RPDs and OSIs compared to reference. 1987 OSIs lower than in 1986. No detectable mounds, but increase in spatial extent of DM in the N-S direction detected from REMOTS (radius estimated to be 500-600 m). Depth of fresh DM estimated as 20 to 30 cm. Spatial coverage of fresh DM estimated as 792,400 sq.meters. Moderate levels of As, low levels of Hg, but Hg high compared to previous site monitoring. No obvious chemical signature of dredged material detected. D#64.

11/5/96

Table 2. Massachusetts Bay Disposal Site summary of past monitoring

Survey Date	Bathymetry	Sediment Profile Imaging	Sediment Chemistry: Metal	PAH	PCB	Pest	O&G	TOC	Water Column Chemistry: Metal	PAH	PCB	Pest	DO	CTD	Tissue Chemistry: Metal	PAH	PCB	Pest	Benthic Comm. Analyses	Major Findings
Oct 87	N	N	8	Y	T	N	Y	Y	N	N	N	N	N	N	F	F	F	N	N	Sediment parameters all relatively low, except for moderate As levels both on- and off-site. The station with fresh DM had the highest means of PHC, PCB, PAH, Pb, Zn, and Cu, but the lowest means of TOC, As, Ni and %fines. Only Zn at one station was sign. greater in top 2 cm than in bottom 2-10 cm. Maximum PAH levels in both sediments & Nephtys were at the station with fresh DM, but a strong statistical difference between on-site and off-site tissue levels was not found. D#75.
Nov 88 - Jan 89	Y	117	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Both old (A) and new (FDA) buoy areas surveyed. At FDA, only 3 stations (100N, CTR, 100S) did not have Stage III taxa; at A, all stations had some Stage III. Compared to reference, OSIs and RPDs were significantly lower at FDA, but not at A. Radius of fresh DM at FDA estimated at 300-350m, with 0.3 m depth of fresh DM detected acoustically since 1/87 survey, but still within DS boundaries. Extent of buoy "A" deposits not mapped, but benthic recovery high, stage 3 communities at all sites near buoy. RPD depths similar to reference areas. D#73.
Dec 88	N	N	9	T	T	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	Sediment chemistry measured at two stations, REF-A and REF-C, in Stellwagen Basin. In general, values were very low, below other MBDS reference levels. PAHs and PCBs were below detection limits. Draft Report from M&E to EPA, 1989.
Jun 89	N	N	7	Y	Y	Y	N	Y	N	N	N	N	N	N	N	N	N	N	N	26 random stations analyzed from the western half of MBDS. Station 12-3 had the highest means of Cr, Cu, Hg and Zn and highest PAHs (6 ppm). Pb (29-155 ppm) was the highest metal relative to regional data. Mean metal values calculated using all site stations were within historic reference site ranges (and national mean from NS&T program), except fo copper. Decrease in PCBs with time noted (only 20 ppb at one station detected). Pesticides detected both on site and at reference. Spatially centered maxima of Cu and PAHs near "A" buoy. Good summary of overall conditions and synthesis with historical sediment chemistry studies. D#91. (Murray, 1989).
Aug 90	Y	80	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	At MDA buoy, a mound 0.8 m high and app. 420 m in diameter was detected with bathymetry. REMOTS detected new DM 400-600 m from center. 260,000 c.m. disposed since 11/88 survey. All stations but 100E supported Stage III benthos. Dominant sere on site and at ref was Stage I on Stage III. Surface roughness sign. greater and RPDs sign. lower on DM compared to ref. OSI values on site generally higher than in Nov. 88, but sign. lower than at ref. Formation of mound said to support use of capping at site. D#92.
Jun-Jul 91	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	EPA-Narragansett study of sediment and tissue chemistry. Indication that MBDS does not have a major impact on tissue chemistry. Sediment levels generally low from the two stations tested. Trend noticed of decreasing tissue concentrations with distance from shore, with MBDS falling between Quincy Bay and Georges Bank. Gardner and Pruell, 1991.

Table 2. Massachusetts Bay Disposal Site summary of past monitoring

Survey Date	Bathymetry	Sediment Profile Imaging	Sediment Chemistry				O&G	TOC	Water Column Chemistry				DO	CTD	Tissue Chemistry				Benthic Comm. Analyses	Major Findings
			Metal	PAH	PCB	Pest			Metal	PAH	PCB	Pest			Metal	PAH	PCB	Pest		
Mar-Apr 9	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Survey of MDA buoy after 1991 storms. 2 distinct mounds formed. Fresh disposal of Boston Blue Clay from CA/THT observed within 200-400 meters of disposal buoy. Relic dredge material observed to 800 m especially to the west. Mound height 2 meters. Stage 1 only found on fresh dredged material (although fresh deposits were devoid of fauna). Stage 3 infauna found away from buoy and throughout area. No evidence of dredged material at any of the three reference areas. Wiley and Charles, 1995. D#100
May 92	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	EPA cruise for whole water (dissolved and particulate) column toxics. At three water depths at MBDS and in the Gulf of Maine. Very low concentrations of trace metals, PAHs, PCBs and pesticides. Battelle, 1992.
Sep 93	Y	N	8	Y	T	Y	N	Y	N	N	N	N	N	N	N	N	N	N	N	Baseline survey of the relocated disposal site. Side scan sonar and SACS studies observed geological features (knolls) and waste barrels, especially in the north, near the old IWS. General area is featureless, sloping to northeast, fine grain silts and clays. MDA buoy is now located in the northeast of the site. Resampling high PAH area, but detection limits still too high. Mound at MDA buoy now 7 meters high. Draft report, DeAngelo and Murray, 1996.
Aug-94	N	78	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Follow up of Sep 93 survey to map areal limits of historical dredged material and benthic recolonization around station 12-3. Includes plan view photos of bottom. MDA buoy shows good recolonization, especially Stage 2 amphipods. Apparent RPD at buoy 1 to 4 cm. Usually Stage 1 on Stage 3. Draft report Murray, 1996.
Sep 94	N	N	8	Y	Y	Y	N	Y	N	N	N	N	Y	Y	L	L	L	L	N	EPA sampling of high PAH area near station 12-3 and IWS for sediment chemistry, toxicity and bioaccumulation. Data presented here in the site management plan. (M&E, 1995)

Legend: #=number of REMOTS stations, or analytes, D#=DAMOS number, DM=dredged material, D=animal deployed in field, F=animal collected in field, L=animal exposed in lab,
N=no, PHC=petroleum hydrocarbons; T=total, Y=yes, BRAT=benthic resource assessment technique

Table 7. Mean (and standard deviation) of tissue concentrations in fish and shellfish collected at the MBDS and the IWS						
AMERICAN PLAICE						
	MBDS, n=3 [1]	MBDS, n=3 [1]	MBDS, n=3 [2]	IWS Site6, n=5 [3]	Stellwagen Basin, n=1 [4]	MBDS, n=1 [4]
	EPA, 1991	EPA, 1991	NOAA, 1992	NOAA, 1992	ADL, 1990	ADL, 1990
	(dry wt)	(wet wt)	(wet wt)	(wet wt)	(wet wt)	(wet wt)
Metals (ug/g)						
Arsenic	—	—	1.03 (0.69)	24.12 (25.12)	1.784	1.561
Cadmium	0.012 (0.03)	0.023	<0.02	0.054 (0.023)	0.002	0.001
Chromium	0.36 (0.55)	0.07	—	3.0 (1.32)	0.04	0.012
Copper	1.580 (0.295)	0.306	—	5.22 (5.62)	0.245	0.379
Lead	0.100 (0.020)	0.019	0.030 (0.005)	1.73 (0.79)	0.089	0.134
Mercury	—	—	0.023 (0.015) [5]	0.188 (0.065)	<0.001	<0.001
Nickel	0.133 (0.188)	0.023	—	—	0.067	0.022
Zinc	60.30 (0.701)	5.04	—	42.4 (11.4)	4.683	5.798
Organics (ng/g)						
Sum PCB [6]	122.89	23.84	<20	<0.06	46.83	102.58
Sum PAHs [7]	19.37 (2.55)	3.79	<12	—	2.832	2.1185

1 mean from 3 individual fish
2 mean from three sites, each site a composite of 24 or 25 individual fish
3 mean from five individual fish
4 one individual fish
5 Methyl mercury
6 Sum of 18 individual PCB congeners (EPA), Aroclor 1254 (NOAA), or Total PCBs (ADL)
7 Sum of 19 (EPA) or 10 (NOAA) or 21 (ADL) individual PAHs

Table 7. Mean (and standard deviation) of tissue concentrations in fish and shellfish collected at the MBDS and the IWS						
LOBSTER	MUSCLE	MUSCLE	TOMALLEY	TOMALLEY	MUSCLE	TOMALLEY
	MBDS, n=3 [1]	MBDS, n=3 [1]	MBDS, n=3 [1]	MBDS, n=3 [1]	MBDS, n=3 [2]	MBDS, n=3 [2]
	EPA, 1991	EPA, 1991	EPA, 1991	EPA, 1991	NOAA, 1992	NOAA, 1992
	(dry wt)	(wet wt)	(dry wt)	(wet wt)	(wet wt)	(wet wt)
Metals (ug/g)						
Arsenic	—	—	—	—	4.286 (3.794)	—
Cadmium	0.055 (.03)	0.011	11.1 (0.6)	5.34	0.11 (0.06)	5.09 (1.38)
Chromium	0.29 (.09)	0.059	0.1 (0.02)	0.05	—	—
Copper	106.93 (21.0)	21.82	111.2 (35.9)	53.6	—	—
Lead	0.163 (.03)	0.033	0.057 (0.05)	0.027	0.053 (0.054)	0.038 (0.06)
Methy mercury	—	—	—	—	0.20 (0.05)	—
Nickel	0.47 (.046)	0.095	0.47 (0.08)	0.23	—	—
Zinc	151.0 (3)	30.8	57.7 (11.7)	27.7	—	—
Organics (ng/g)						
Sum PCBs [3]	49.79 (25.9)	10.151	2359.9 (567.5)	1132.8	<100	623 (340)
Sum PAHs [4]	81.4 (33.0)	13.666	1186.5 (335.1)	569.5	0.10 (0.07)	1114 (1001)

1 mean from 3 individual lobsters

2 mean from three sites, each site a composite of 15 or 20 individual lobsters

3 Sum of 18 PCB congeners (EPA) or Aroclor 1254 (NOAA)

4 Sum of 19 (EPA) or 10 (NOAA) individual parent PAHs

Table 7. Mean (and standard deviation) of tissue concentrations in fish and shellfish collected at the MBDS and the IWS		
QUAHOG		
	MBDS, n=1[1]	MBDS, n=1[1]
	EPA, 1991	EPA, 1991
	(dry wt)	(wet wt)
Metals (ug/g)		
Cadmium	3.46	0.401
Chromium	1.26	0.146
Copper	48.6	5.63
Lead	5.8	0.673
Mercury	—	—
Nickel	28.2	3.271
Zinc	236	27.376
Organics (ng/g)		
Sum PCBs[2]	66.63	7.72908
Sum PAHs[3]	279.18	32.38488

1 one individual

2 Sum of 18 PCB congeners (EPA) or Aroclor 1254 (NOAA)

3 Sum of 19 (EPA) or 10 (NOAA) individual PAHs == this will be standardized

Table 8. 1994 EPA sampling of MBDS for sediment chemistry									
	REFERENCE	Q	STATION1 (12-3)	Q	STATION1-DUP	Q	STATION1 AVG	STATION2 (IWS)	Q
COORDINATES	42 21.6'N, 70 25.1'W		42 25.5'N, 70 35.4'W					42 25.5'N, 70 35.9'W	
TOC (%)	1.98		2.8		2.8		2.8	3.3	
TOTAL SOLIDS (% w/w)	46.4		40.9		42.5		41.7	35.5	
METALS (ug/g):									
Arsenic	10.8		10.7		13.5		12.1	14.4	
Cadmium	0.05	U	0.07	U	0.05	U	0.06	0.06	U
Chromium	59	E	74.4	E	86.9	E	80.65	92.5	E
Copper	16.4	E*	35.4	E*	48.8	E*	42.1	34.7	E*
Lead	30.6	E	57.5	E	70.4	E	63.95	59.7	E
Mercury	0.12	N	0.32	N	0.27	N	0.295	0.24	N
Nickel	20.7	E	20	E	25	E	22.5	31.4	E
Zinc	74.5	EN	90.4	EN	115	EN	102.7	110	EN

QUALIFIERS (Q)

U - Entered if the analyte was analyzed for but not detected, less than Instrument Detection Limit (IDL).

E - The reported value is estimated because of the presence of interference.

* - Duplicate analysis not within control limits.

N - Matrix spiked sample recovery not within control limits.

B - Entered if the reported value is less than the Contract Required Detection Limit (CRDL), but greater than the IDL

< - less than detection limit

11/5/96

Table 8. 1994 EPA sampling of MBDS for sediment chemistry										
	REFERENCE	Q	STATION1 (12-3)	Q	STATION1-DUP	Q	STATION1 AVG	STATION2 (IWS)	Q	
COORDINATES	42 21.6'N, 70 25.1'W		42 25.5'N, 70 35.4'W					42 25.5'N, 70 35.9'W		
PAHs (ug/kg):										
Napthalene	29	U	387		435		411	871		
2-Methylnaphthalene	29	U	92		126		109	130		
1-Methylnaphthalene	29	U	55		79		67	82		
1,1-Biphenyl	29	U	39		36		37.5	37	U	
2,6-Dimethylnaphthalene	29	U	61		66		63.5	41		
Acenaphthylene	29	U	92		71		81.5	107		
Acenaphthene	29	U	97		140		118.5	71		
2,3,5-Trimethylnaphthalene	29	U	64		36		50	37	U	
Fluorene	29	U	201		193		197	37	U	
Phenanthrene	105		1466		1293		1379.5	760		
Anthracene	29	U	754		502		628	286		
1-Methylphenanthrene	29	U	276		193		234.5	160		
Fluoranthene	184		2808		2250		2529	2196		
Pyrene	166		2772		2369		2570.5	2210		
Benz(a)anthracene	74		1605		1252		1428.5	1361		
Chrysene	101		1441		1113		1277	1184		
Benzo(b)fluoranthene	130		1563		1113		1338	1407		
Benzo(k)fluoranthene	52		1127		979		1053	1047		
Benzo(e)pyrene	68		999		778		888.5	915		
Benzo(a)pyrene	94		1686		1225		1455.5	1475		
Perylene	29	U	379		287		333	297		
Indeno(1,2,3-cd)pyrene	74		848		666		757	827		
Dibenzo(a,h)anthracene	29	U	196		156		176	200		
Benzo(g,h,i)perylene	62		617		481		549	593		

Table 8. 1994 EPA sampling of MBDS for sediment chemistry									
	REFERENCE	Q	STATION1 (12-3)	Q	STATION1-DUP	Q	STATION1 AVG	STATION2 (IWS)	Q
COORDINATES	42 21.6'N, 70 25.1'W		42 25.5'N, 70 35.4'W					42 25.5'N, 70 35.9'W	
PCBs (ug/kg):									
BZ#8	1.7	U	12		12		12	2.4	U
BZ#18	1.7	U	29		29		29	2.4	U
BZ#28	1.7	U	67		71		69	6.7	
BZ#44	1.7	U	33		35		34	3.5	
BZ#52	1.7	U	29		29		29	4.2	
BZ#66	1.7	U	30		31		30.5	9	
BZ#101	1.7	U	20		24		22	7.7	
BZ#105	1.7	U	11		9.8		10.4	8.1	
BZ#118	1.7	U	20		19		19.5	14	
BZ#126	1.5	U	6.3		3.2		4.75	5.2	
BZ#128	1.5	U	3.9		3.3		3.6	3	
BZ#138	1.5	U	20		12		16	14	
BZ#153	1.7	U	17		13		15	18	
BZ#170	1.5	U	6.3		2.7		4.5	5.5	
BZ#180	1.5	U	9.3		5.4		7.35	12	
BZ#187	1.5	U	3.9	U	1.8	U	2.85	2.3	U
BZ#195	1.5	U	3.9	U	1.8	U	2.85	2.3	U
BZ#206	1.5	U	3.9	U	1.9		2.9	2.3	U
BZ#209	1.5	U	3.9	U	1.8	U	2.85	2.3	U

Table 8. 1994 EPA sampling of MBDS for sediment chemistry									
	REFERENCE	Q	STATION1 (12-3)	Q	STATION1-DUP	Q	STATION1 AVG	STATION2 (IWS)	Q
COORDINATES	42 21.6'N, 70 25.1'W		42 25.5'N, 70 35.4'W					42 25.5'N, 70 35.9'W	
Pesticides (ug/kg):									
Hexachlorobenzene	1.7	U	4	U	1.9	U	2.95	2.4	U
gamma-BHC	1.7	U	4	U	1.9	U	2.95	2.4	U
Heptachlor	1.7	U	4	U	1.9	U	2.95	2.4	U
Aldrin	1.7	U	4	U	1.9	U	2.95	2.4	U
Heptachlor Epoxide	1.7	U	4	U	1.9	U	2.95	2.4	U
alpha-Chlordane	1.7	U	4	U	1.9	U	2.95	2.4	U
gamma-Chlordane	1.7	U	4	U	1.9	U	2.95	2.4	U
Technical chlordane	42	U	98	U	88	U	93	110	U
Endosulfan I	1.7	U	4	U	1.9	U	2.95	2.4	U
2,4-DDT	1.7	U	4	U	1.9	U	2.95	2.4	U
4,4-DDT	1.5	U	140		1.8	U	70.9	2.3	U
2,4-DDD	1.7	U	9.6		8.5		9.05	3.9	
4,4-DDD	1.7	U	26		15		20.5	7.7	
2,4-DDE	1.7	U	4	U	1.9	U	2.95	2.4	U
4,4-DDE	1.7	U	6.7		5.1		5.9	3	
trans-Nonachlor	1.7	U	4	U	1.9	U	2.95	3.3	
Dieldrin	1.7	U	4	U	1.9	U	2.95	2.4	U
Endrin	3.3	U	7.9	U	3.7	U	5.8	4.7	U
Endosulfan II	3.3	U	7.9	U	3.7	U	5.8	4.7	U
Endosulfan sulfate	3.3	U	7.9	U	3.7	U	5.8	4.7	U
Methoxychlor	15	U	39	U	18	U	28.5	23	U
Mirex	1.5	U	3.9	U	1.8	U	2.85	2.3	U
Toxaphene	170	U	390	U	350	U	370	440	U

Table 9. Sediment quality at Massachusetts Bay Disposal Site stations and Reference Areas compared to regional sediment quality.

			Metals (ug/g dry wt)								Organics (ng/g dry wt)				
LOCATION	DATA SOURCE	DATE	ARSENIC	CADMIUM	CHROMIUM	COPPER	LEAD	MERCURY	NICKEL	ZINC	Total PCBs [1]	Total DDTs [3]	Total PAHs	LMW PAHs [4]	HMW PAHs [7]
Reference Stations															
Mean Ref. Stations	SAIC, 1994	1985-1987			56	20.8	56.3		27.8	98.8					
Mean Ref. Stations	SAIC, 1994	June, 1989			73.5	29	50		23.5	116	nd [2]	7.45	65	nd	65
Mean Ref. Stations	SAIC, 1995	1989-1993	15.7	1.06	79.8	19.7	46.7	0.121	25.1	90			2352	268	2060
1994 Ref. Station	M&E, 1995 (EPA)	Sept, 1994	10.8	0.03	59	16.4	30.6	0.12	20.7	74.5	15.3	5.1	1130	178	952
Disposal Site Stations															
Mean MBDS	SAIC, 1994	June, 1989			70	44	72		21	127			1308	164 [5]	1144
Station 12-3	SAIC, 1994	June, 1989			139	74	110	0.47	16	221	nd [2]		8002	1500 [6]	6520
Station 12-3	SAIC, 1996	Sept, 1993	12	1.7	95	44	71	0.101	26	129			21600	6500 [6]	15100
MBDS South	Gardner and Pruell, 1991 (EPA) [8]	May, 1991		0.54	35.7	15.7	3.08		25.9	72.7	2.3	4.1	178.3	27.3	151
IWS North	Gardner and Pruell, 1991 (EPA) [8]	May, 1991		0.36	40.8	16.4	3.19		26.2	78.4	1.2	1.1	32.4	6.6	25.8
Station 12-3	M&E, 1995 (EPA)	Sept, 1994	12.1	0.03	80.7	42.1	64	0.3	22.5	102.7	318.1	112.3	15950	2816	13134
IWS	M&E, 1995 (EPA)	Sept, 1994	14.4	0.03	92.5	34.7	59.7	0.24	31.4	110	117.9	16.7	14614	2114	12500
Regional or local levels															
NS&T National Mean	SAIC, 1994	1985-1989			110	35	43	0.17	34	140					
NS&T National "High"	SAIC, 1994	1985-1989			230	84	89	0.49	69	270					
Boston Harbor	Long et al., 1996 (NOAA)						144.4				268		14804		

1 Sum of 18 or 19 congeners
2 Total PCBs
3 Sum of DDT, DDE and DDD
4 Sum of six 2 and 3 ring parent PAHs
5 Napthalene and phenanthrene only
6 Phenanthrene only
7 Sum of nine, 4 and 5 ring parent PAHs only
8 Organics levels extremely low, probable outliers

Table 10. Bioaccumulation in *Macoma* (dry weight)

	Reference Average	Reference Std Dev.	Reference Qualifiers (a)	12-3 (Station 1) Average	12-3 Std Dev.	12-3 Qualifiers	IWS (Station 2) Average	IWS Std Dev.	IWS Qualifiers	p Value	Significant Differences (b,c)
METALS (mg/kg):											
Arsenic	3.5	0.100		3.54	0.270		3.38	0.217		0.4719	
Cadmium	0.044	0.005	B	0.048	0.004	B	0.042	0.008	B	0.3444	
Chromium	0.348	0.045	B	0.462	0.039		0.376	0.093	B	0.0383	REF<12-3
Copper	2.12	0.084		3.04	0.344		2.18	0.409		0.0008	REF<12-3
Lead	2.08	0.217	E*	2.38	0.192	E*	1.68	0.110	E*	0.0002	IWS<REF
Mercury	0.032	0.027		0.534	1.100		0.02	0.000		0.3746	
Nickel	0.5	0.039	B	0.82	0.556	B	0.426	0.033	B	0.1637	
Zinc	13.66	0.770	E	14.42	1.266	E	14.06	1.399	E	0.6062	

(a) Predominant qualifiers among the five replicates, if any
(b) Means, standard deviations and statistical differences were calculated using one half detection limits for concentrations below detection limits
(c) Denotes stations significantly different from the Reference station at the 0.050 level
(d) Merged with benzo(b)fluoranthene
U - Analyte was analyzed for but not detected, less than Instrument Detection Limit (IDL).
E - The reported value is estimated because of the presence of interference.
* - Duplicate analysis not within control limits.
N - Matrix spiked sample recovery not within control limits.
B - Entered if the reported value is less than the Contract Required Detection Limit (CRDL)
but greater than the Instrument Detection Limit (IDL).

Table 10. Bioaccumulation in *Macoma* (dry weight)

	REFERENCE			12-3 (Station 1)			IWS (Station 2)			p	Significant
	Average	Std Dev.	Qualifiers (a)	Average	Std Dev.	Qualifiers	Average	Std Dev.	Qualifiers	Value	Differences (b,c)
PAHs (ug/kg):											
Napthalene	14.8	3.114		26.4	2.608		23	7.969		0.0113	REF<12-3
2-Methylnaphthalene	19.4	4.561		25.2	2.387		25.8	15.287		0.5065	
1-Methylnaphthalene	6.4	2.104	U	12	1.000		U		U	0.0007	REF<12-3
1,1-Biphenyl	U		U	7.3	2.950	U	8.3	7.678	U	0.6313	
2,6-Dimethylnaphthalene	6.4	2.104		12.4	6.618		U		U	0.0629	
Acenaphthylene	U		U	U		U	U		U		
Acenaphthene	U		U	6.1	2.191	U	U		U	0.8363	
2,3,5-Trimethylnaphthalene	U		U	38	37.222		11.9	11.404	U	0.0910	
Fluorene	U		U	18.6	7.021		U		U	0.0006	REF<12-3
Phenanthrene	54	6.819		158.2	30.671		87.4	26.369		0.0001	REF<12-3
Anthracene	U		U	81	21.726		35	11.937		0.0000	REF<12-3, IWS
1-Methylphenanthrene	6.6	2.535	U	38	13.435		16.6	8.503		0.0006	REF<12-3
Fluoranthene	61	11.937		414	53.111		301.4	67.300		0.0000	REF<12-3, IWS
Pyrene	106	105.155		1105	191.068		1057.6	187.153		0.0000	REF<12-3, IWS
Benz(a)anthracene	18	5.657		348	43.338		325.8	73.053		0.0000	REF<12-3, IWS
Chrysene	21.8	5.586		224	25.733		211.6	32.455		0.0000	REF<12-3, IWS
Benzo(b)fluoranthene	48	10.700		283	65.930		443	116.780		0.0000	REF<12-3, IWS
Benzo(k)fluoranthene (d)											
Benzo(e)pyrene	98.8	172.881		113	27.468		218.6	59.589		0.1950	
Benzo(a)pyrene	93	168.287		147	32.784		275.4	86.869		0.0608	
Perylene	48.8	80.627		28	8.689		55.4	17.644		0.6508	
Indeno(1,2,3-cd)pyrene	60	94.525		48	12.239		74.4	24.141		0.7612	
Dibenzo(a,h)anthracene	U		U	15.7	6.140		20.3	7.887		0.0046	REF<12-3, IWS
Benzo(g,h,i)perylene	93.8	187.411		14.7	7.068		59.8	15.991		0.5315	

Table 10. Bioaccumulation in *Macoma* (dry weight)												
		REFERENCE			12-3 (Station 1)			IWS (Station 2)			p Value	Significant Differences (b,c)
		Average	Std Dev.	Qualifiers (a)	Average	Std Dev.	Qualifiers	Average	Std Dev.	Qualifiers		
PCBs (ug/kg):												
BZ#8		3.93	2.141		202	85.849		5.76	2.466		0.0000	REF<12-3
BZ#18		1.6	0.552		250	168.671		2.6	0.735		0.0021	REF<12-3
BZ#28		3.8	0.534		1428	707.050		11.5	3.841		0.0001	REF<12-3
BZ#44		U		U	212	139.714		2.1	0.731		0.0017	REF<12-3
BZ#52		2.96	0.937		650	367.219		10.2	2.877		0.0005	REF<12-3
BZ#66		1.82	0.694		626	276.460		13	2.550		0.0001	REF<12-3
BZ#77		U		U	111.6	85.912		2.633	2.943		0.0057	REF<12-3
BZ#101		1.92	0.614		346	154.693		11.88	1.781		0.0001	REF<12-3
BZ#105		1.83	1.005		128.6	58.153		5.28	1.167		0.0001	REF<12-3
BZ#118		2.72	0.887		292	133.116		11.44	1.752		0.0001	REF<12-3
BZ#126		U		U	U		U	6.45	12.047	U	0.3737	
BZ#128		U		U	U		U	5.08	3.897		0.0101	REF<12-3
BZ#138		4.82	1.934		214	40.373		27.2	9.445		0.0000	REF<12-3
BZ#153		3.42	1.050		163.6	76.778		13.6	2.074		0.0001	REF<12-3
BZ#170		U		U	U		U	2.58	2.287		0.0007	REF<12-3
BZ#180		1.55	0.887	U	U		U	5.32	1.057		0.0002	REF<12-3, IWS
BZ#187		1.32	0.375		U		U	11.98	12.337		0.1058	
BZ#195		U		U	U		U	U		U		
BZ#206		U		U	U		U	U		U		
BZ#209		U		U	U		U	U		U		

Table 10. Bioaccumulation in *Macoma* (dry weight)

		REFERENCE			12-3 (Station 1)			IWS (Station 2)			p	Significant
		Average	Std Dev.	Qualifiers (a)	Average	Std Dev.	Qualifiers	Average	Std Dev.	Qualifiers	Value	Differences (b,c)
Pesticides (ug/kg):												
Hexachlorobenzene		1.03	0.994	U	U		U	U		U	0.0011	REF<12-3
gamma-BHC		0.79	0.270		10.83	14.685	U	U		U	0.1557	
Heptachlor		U		U	40.4	36.295		3.258	6.005	U	0.0204	REF<12-3
Aldrin		U		U	U		U	U		U		
Heptachlor Epoxide		U		U	U		U	U		U		
alpha-Chlordane		U		U	128	95.934		1.5	0.543		0.0044	REF<12-3
gamma-Chlordane		U		U	U		U	U		U		
Technical chlordane		U		U	U		U	U		U		
Endosulfan I		U		U	U		U	1.532	0.754		0.0870	
2,4-DDT		U		U	U		U	U		U		
4,4-DDT		U		U	U		U	U		U		
2,4-DDD		U		U	U		U	1.495	2.020	U	0.0020	REF<12-3
4,4-DDD		U		U	332	126.372		17.6	4.980		0.0000	REF<12-3
2,4-DDE		U		U	113.2	59.222		2.82	0.421		0.0003	REF<12-3
4,4-DDE		0	5.751		139.6	70.088		7.26	1.587		0.0002	REF<12-3
trans-Nonachlor		U		U	U		U	U		U		
Dieldrin		0	2.566		142	133.626		6.272	3.568		0.0222	REF<12-3
Endrin		U		U	U		U	U		U		
Endosulfan II		U		U	29.3	31.555	U	U		U	0.0511	
Endosulfan sulfate		U		U	U		U	U		U		
Methoxychlor		U		U	U		U	U		U		
Mirex		U		U	U		U	U		U		
Toxaphene		U		U	U		U	U		U		

Table 11. Bioaccumulation in *Nereis* (dry weight)											
	REFERENCE			12-3 (Station 1)			IWS (Station 2)			p	Significant
	Average	Std Dev.	Qualifiers (a)	Average	Std Dev.	Qualifiers	Average	Std Dev.	Qualifiers	Value	Differences (b, c)
METALS (mg/kg):											
Arsenic	2.86	0.152	E	2.66	0.195	E	2.64	0.207	E	0.1610	
Cadmium	0.06	0.017	B	0.058	0.004	B	0.058	0.004	B	0.9431	
Chromium	0.152	0.019	B	0.168	0.016	B	0.148	0.013	B	0.1684	
Copper	1.68	0.409	E	1.96	0.055	E	1.66	0.114	E	0.1421	
Lead	0.5	0.058		0.506	0.040		0.354	0.173		0.0773	
Mercury	0.032	0.004		0.036	0.005		0.044	0.005		0.0097	REF<IWS
Nickel	0.542	0.061	B	0.476	0.034	B	0.398	0.029	B	0.0008	REF<IWS
Zinc	16.04	6.280	EN*	33.98	7.257	EN*	29.22	13.420	EN*	0.0301	REF<12-3

(a) Predominant qualifiers among the five replicates, if any

(b) Means, standard deviations and statistical differences were calculated using one half detection limits for concentrations below detection limits

(c) Denotes stations significantly different from the Reference station at the 0.050 level

(d) Merged with benzo(b)fluoranthene

U - Analyte was analyzed for but not detected, less than Instrument Detection Limit (IDL).

E - The reported value is estimated because of the presence of interference.

* - Duplicate analysis not within control limits.

N - Matrix spiked sample recovery not within control limits.

B - Entered if the reported value is less than the Contract Required Detection Limit (CRDL) but greater than the Instrument Detection Limit (IDL).

Table 11. Bioaccumulation in *Nereis* (dry weight)

	REFERENCE Average	Std Dev.	Qualifiers (a)	12-3 (Station 1) Average	Std Dev.	Qualifiers	IWS (Station 2) Average	Std Dev.	Qualifiers	p Value	Significant Differences (b, c)
PAHs (ug/kg):											
Napthalene	29.1	28.732		15.2	3.271		72.8	49.777		0.0442	
2-Methylnaphthalene	22.5	13.766		18.4	3.507		17.2	11.432		0.7127	
1-Methylnaphthalene	11.1	5.296	U	8.2	3.194	U	10.1	5.177	U	0.6184	
1,1-Biphenyl	U		U	U		U	18.2	12.276		0.0523	
2,6-Dimethylnaphthalene	U		U	U		U	U		U		
Acenaphthylene	U		U	U		U	U		U		
Acenaphthene	U		U	8.2	3.194	U	U		U	0.9294	
2,3,5-Trimethylnaphthalene	U		U	U		U	U		U		
Fluorene	9.5	5.123	U	U		U	U		U	0.4500	
Phenanthrene	18	10.271		30.6	2.966		31.8	11.713		0.1473	
Anthracene	U		U	11.8	8.843	U	U		U	0.5817	
1-Methylphenanthrene	U		U	U		U	U		U		
Fluoranthene	9.9	5.962	U	24.2	9.121		33.8	28.613		0.1412	
Pyrene	20.4	7.956		63.6	8.081		106.6	40.470		0.0004	REF<12-3, IWS
Benz(a)anthracene	U		U	8	2.828	U	U		U	0.9380	
Chrysene	U		U	28.8	4.438		41.2	9.808		0.0000	REF<12-3, IWS
Benzo(b)fluoranthene	9.5	5.123	U	26.6	7.987		32.8	10.663		0.0021	REF<12-3, IWS
Benzo(k)fluoranthene (d)											
Benzo(e)pyrene	U		U	14.8	3.834	U	25.4	9.209		0.0016	REF<IWS
Benzo(a)pyrene	U		U	12	5.701		18.7	12.122		0.0949	
Perylene	10.3	6.815	U	8.2	3.194	U	12.4	9.959	U	0.6635	
Indeno(1,2,3-cd)pyrene	U		U	U		U	U		U		
Dibenzo(a,h)anthracene	U		U	U		U	U		U		
Benzo(g,h,i)perylene	U		U	U		U	U		U		

		REFERENCE			12-3 (Station 1)			IWS (Station 2)			p	Significant
		Average	Std Dev.	Qualifiers (a)	Average	Std Dev.	Qualifiers	Average	Std Dev.	Qualifiers	Value	Differences (b, c)
PCBs (ug/kg):												
BZ#8		U		U	U		U	1.72	0.382	U	0.0508	
BZ#18		U		U	13.6	1.817		U		U	0.0000	REF<12-3
BZ#28		2.07	0.931	U	12.98	2.480		6.46	1.062		0.0000	REF<12-3, IWS
BZ#44		U		U	4.42	1.165		U	.	U	0.0000	REF<12-3
BZ#52		1.49	0.621	U	35.6	3.286		9.98	0.642		0.0000	REF<12-3, IWS
BZ#66		U		U	34.2	5.541		17.6	1.817		0.0000	REF<12-3, IWS
BZ#77		U		U	4.84	3.087		3.17	2.832	U	0.2210	
BZ#101		U		U	18	5.148		9.7	1.292		0.0000	REF<12-3, IWS
BZ#105		U		U	12.6	1.673		5.44	2.732		0.0000	REF<12-3, IWS
BZ#118		U		U	11.76	1.841		6.7	1.598		0.0000	REF<12-3, IWS
BZ#126		U		U	U		U	5.14	6.334	U	0.3241	
BZ#128		2.24	0.429	U	7.36	1.258		5.27	2.910		0.0020	REF<12-3, IWS
BZ#138		U		U	29	8.803		37.8	14.167		0.0005	REF<12-3, IWS
BZ#153		4.78	2.678		15.93	20.591	U	38.6	7.701		0.0075	REF<IWS
BZ#170		8.23	3.453		7.38	1.040		9.18	2.825		0.0001	REF<12-3, IWS
BZ#180		U		U	14.6	3.647		17.8	4.970		0.0000	REF<12-3, IWS
BZ#187		2.34	0.612	U	11	1.838		18.8	7.918		0.0006	REF<12-3, IWS
BZ#195		2.54	1.027	U	U		U	U		U		
BZ#206		U		U	U		U	4.07	1.362	U	0.0018	REF<IWS
BZ#209		U		U	U		U	3.67	1.338	U	0.0070	REF<IWS

Table 11. Bioaccumulation in *Nereis* (dry weight)

Table 11. Bioaccumulation in *Nereis* (dry weight)											
	REFERENCE			12-3 (Station 1)			IWS (Station 2)			p	Significant
	Average	Std Dev.	Qualifiers (a)	Average	Std Dev.	Qualifiers	Average	Std Dev.	Qualifiers	Value	Differences (b, c)
Pesticides (ug/kg):											
Hexachlorobenzene	1.86	1.567	U	U		U	U		U	0.5311	
gamma-BHC	U		U	2.58	1.043		U		U	0.0259	REF<12-3
Heptachlor	1.62	1.135	U	2.84	1.379		U		U	0.1357	
Aldrin	U		U	U		U	U		U		
Heptachlor Epoxide	U		U	3.68	0.396		U		U	0.0063	REF<12-3
alpha-Chlordane	U		U	6.8	0.458		4.01	2.088		0.0002	REF<12-3
gamma-Chlordane	U		U	U		U	U		U		
Technical chlordane	U		U	U		U	U		U		
Endosulfan I	U		U	3.88	1.787		1.96	0.243	U	0.0243	
2,4-DDT	U		U	U		U	U		U		
4,4-DDT	5.28	3.311		U		U	U		U	0.0744	
2,4-DDD	U		U	5.52	4.125		4.39	3.217		0.2146	
4,4-DDD	U		U	15.92	8.083		U		U	0.0005	REF<12-3
2,4-DDE	U		U	5	2.281		2.34	0.484	U	0.0092	REF<12-3
4,4-DDE	U		U	7.72	1.003		2.36	0.463	U	0.0000	REF<12-3
trans-Nonachlor	U		U	U		U	4.92	3.400		0.0331	
Dieldrin	U		U	9.92	1.184		5.04	0.799		0.0000	REF<12-3, IWS
Endrin	U		U	U		U	U		U		
Endosulfan II	U		U	U		U	U		U		
Endosulfan sulfate	U		U	4.42	1.923	U	U		U	0.5022	
Methoxychlor	U		U	U		U	U		U		
Mirex	U		U	U		U	U		U		
Toxaphene	U		U	U		U	U		U		

Table 12. Range of tissue concentrations (dry weight) in polychaetes collected at MBDS					
	Nephtys	Nephtys	Nephtys	Nephtys	Nereis
	Reference	Reference	Disposal mound	Off disposal mound	Bioaccumulation test
	1990	1985 - 1987	1985 - 1986	1985 - 1986	(See Table 11)
	ADL, 1990	Hubbard, 1988	Hubbard, 1988	Hubbard, 1988	M&E, 1994
METALS (mg/kg)					
Arsenic	nd[1] - 43	6.23 - 89.7	18.9 - 19.7	31	2.64 - 2.86
Cadmium	0.45 - 0.70	0.68 - 1.12	0.53 - 0.97	0.67 - 0.78	0.04 - 0.06
Chromium	0.51 - 1.17	0.64 - 0.66	0.78 - 1.39	0.65	0.14 - 0.17
Copper	5.1 - 12.3	6.30 - 13.4	7.3 - 15.7	7.18 - 14.1	1.66 - 1.96
Lead	2.3 - 4.1	3.84 - 4.6	3.27 - 6.08	4.69 - 9.6	0.35 - 0.51
Mercury	0.037 - 0.068	nd - 0.07	nd - 0.08	nd - 0.03	0.03 - 0.04
Nickel	2.3 - 3.8	–	–	–	0.39 - 0.54
Zinc	121 - 252	177 - 223	181 - 216	233	16.04 - 33.98
Total PCBs (mg/kg)	0.026 - 0.17	0.15 - 0.475	0.70 - 2.5	0.43 - 1.05	0.02 - 0.23[2]
Sum DDTs (mg/kg)	0.001 - 0.011	0.02 - 0.03	–	–	0.005 - 0.034
PAHS (ug/kg)					
Fluorene	nd	10.9 - 11.0	25	nd - 17.5	nd - 9.5
Phenanthrene	7.1 - 20	37.5 - 64.2	61.4	nd - 42.6	18 - 31.8
Anthracene	nd - 19	4.2 - 22.4	114.6	33.7 - 91.3	nd - 11.8
Fluoranthene	19 - 49	4.48 - 51.9	408.3	135.7 - 139.6	9.9 - 33.8
Pyrene	24 - 71	58.1 - 50.5	365.2	158.3 - 327.0	20.4 - 106.6
Benz(a)anthracene	4.1 - 15	nd - 118.4[3]	1089.6[3]	nd - 1192.7[3]	nd
Chrysene	14 - 29	—	—	—	nd - 53
Benzo(b and k)fluoranthene	5.2 - 32	nd - 9.9	35.7	nd - 41.7	9.5 - 32.8
Benzo(a)pyrene	19 - 59	nd - 53.8	261.9	nd - 394.5	nd - 18.7
Indeno(1,2,3-cd)pyrene	nd - 9.5	nd	nd - 65.7	nd	nd
Benzo(g,h,i)perylene	10 - 34	nd	93.4	nd - 77.0	nd
Dibenzo(a,h)anthracene	nd	nd	nd	nd	nd

1 nd = not detected
2 Sum of measured PCB congeners
3 Benz(a)anthracene and Chrysene

MBDSPOLY.XLS

4/5/96

Table 13. MBDS Reference Stations

STATION	LATITUDE[1]	LONGITUDE[1]	LOCATION	DEPTH (M)	DATES SAMPLED
MUD-REF (18-17)	42 24.7	70 32.8	1.2 nmi SE from MBA buoy	80	1985 - 1992
FG-23	42 22.8	70 34.4	2.5 nmi S from MBA buoy	85	1987 - 1992
SE	42 20.0	70 28.0	6.8 nmi SE from MBA buoy	90	1987 - 1992
REF-A	42 22.7	70 30.3	3.9 nmi SE from MBA buoy	90	1988 - 1994
1994 REF	42 21.6	70 30.3	7.6 nmi SE from MBA buoy	90	1994

1 Decimal degrees

XI. APPENDIX A -- LIBRARIES WHICH RECEIVE DAMOS TECHNICAL REPORTS

BOSTON UNIVERSITY LIBRARY
CAMBRIDGE MA 02138

GEORGE PERKINS MARSH INSTITUTE LIBRARY
CLARK UNIVERSITY
WORCESTER MA 01610-1477

HARVARD UNIVERSITY LIBRARY
CAMBRIDGE MA 02138

HEALEY LIBRARY-STANDING ORDERS
UNIVERSITY OF MASSACHUSETTS
BOSTON HARVARD CAMPUS
BOSTON MA 02125-3393

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE MA 02139

NORTHEASTERN UNIVERSITY LIBRARY
MARINE SCIENCE AND MARITIME
STUDIES CENTER
NAHANT MA 01908

SOUTHESTERN MASSACHUSETTS UNIVERSITY LIBRARY
NORTH DARTMOUTH MA 02747